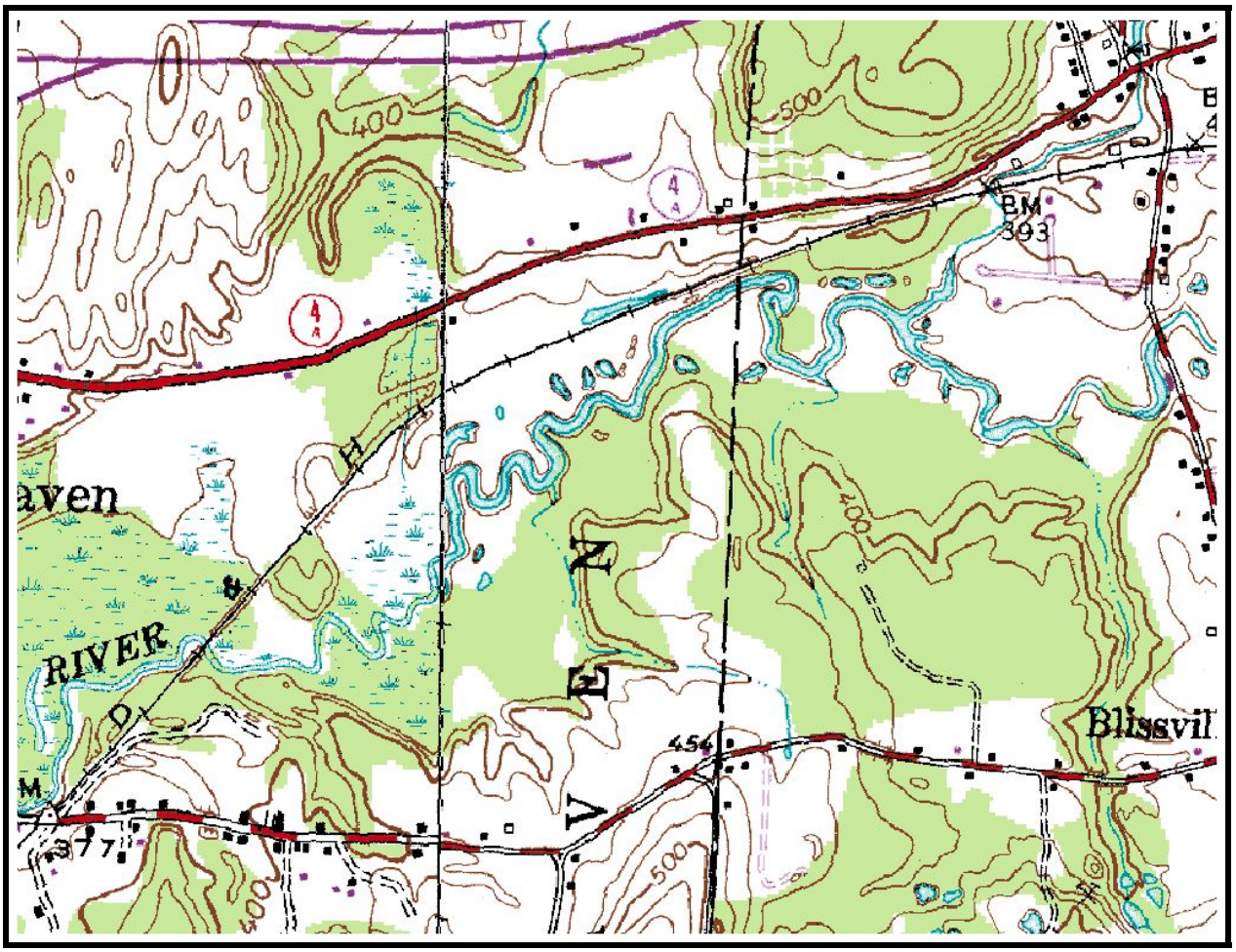
# Vermont Stream Geomorphic Assessment
# Phase 1 Handbook

# WATERSHED ASSESSMENT




## USING MAPS, EXISTING DATA, AND WINDSHIELD SURVEYS

**Vermont Agency of Natural Resources**
**May, 2007**

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**Funding for assessment protocol development has been provided by the:**

**U.S. Environmental Protection Agency**
**U.S Fish and Wildlife Service – Conservation and Reinvestment Act Funding**
**Federal Emergency Management Agency**
**Lake Champlain Basin Program**
**Vermont Agency of Transportation Research Grant**
**Vermont Geological Survey State Map Grant**

**Acknowledgements:** Other Agency of Natural Resources staff who worked on the Phase 1 Handbook include Jim Ryan and Ethan Swift (of the Water Quality Division Planning Section), Jared Carrano, Leslie Fernandez and Sacha Pealer (of the Water Quality Division River Management Program) and Joe Zuccarello (Department of Fish and Wildlife). Special thanks and acknowledgement to Brenda Clarkson and Andrew Tomczak of the ANR Information Technology Section for developing the Web-based data management system (DMS). An initial draft outline of the Phase 1 Handbook was provided through contracted services with Lori Barg of Step by Step Consulting. Pilot projects which greatly enhanced the development of the Phase 1 Handbook were made possible by Michele Boomhower of the Lamoille County Regional Commission; Marty Illick and Kristen Underwood (and many volunteers) of the Lewis Creek Association; Amy Sheldon and Dan McKinley (and many volunteers) of the White River Partnership; Shelly Stiles and Dick Schesinger (and many volunteers) of the Bennington area; and Jed Wright of the USFWS Gulf of Maine Coastal program (Cove Creek pilot project, Central, Maine).

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The Phase 1 Handbook may be downloaded from the River Corridor Management, Geomorphic Assessment internet web page at: **www.vtwaterquality.org/rivers.htm**

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* The Vermont ANR Stream Geomorphic Assessment Handbooks, Phases 1 through 3, have a shared set of appendices. Not all appendices are included with the Phase 1 Handbook.

# PHASE 1 INTRODUCTION

This Handbook is a guide to the Phase 1 Watershed Assessment, the first of 3 phases of the Vermont Stream Geomorphic Assessment protocols. Phase 1 is carried out using existing data such as topographic maps, orthophotos, agencies' and organizations' databases, local and resource specialists' knowledge, and "windshield surveys." Windshield surveys provide field data through quick observation without extensive field measurements.

The data collected in a Phase 1 assessment provide an overview of the general physical characteristics of a watershed. Maps, aerial pictures, and historic information will be invaluable when combined with field interpretations in piecing together the story of a stream's response to the natural and human disturbances that have occurred over time at the watershed scale.

## Where to Complete a Phase 1 Watershed Assessment

Where to complete a Phase 1 watershed assessment is largely a question of scale, as well as local priorities. How much of the main stem should be assessed? Which tributaries should be looked at? It is highly recommended that you and your team review the parameters (or characteristics) described in this handbook. A limited assessment of stream reaches and tributaries will produce information you need to solve problems, but only if your team examines enough of the watershed to interpret the impacts associated with upstream and downstream activities.

## Final Products of the Phase 1 Watershed Assessment

Products of a Phase 1 Watershed Assessment include:

1. **Reference Stream Typing,** which involves dividing streams in the watershed into geomorphic "reaches" that are assigned a "reference stream type" based on physical parameters such as geology, valley landform, and valley slope. **Note:** These are NOT the stream types as described in the Vermont Water Quality Standards classification scheme (Water Resources Board, 1999).

2. A **Stream Impact Rating** that results in a priority ranking for each reach in your watershed (Step 8). This is based on impact scores that you assign to channel, floodplain, and land use modifications for each reach as you progress through the assessment. Reaches with high scores may be physically responding to disturbances and warrant further study in the field. Reaches with very low scores may also be candidates for field assessment as they may be suitable reference reaches for streams in adjustment.

3. A **Provisional Geomorphic Condition Evaluation** for each reach (Step 9) that includes:
   - **Reach Condition,** a descriptor that represents an estimate of channel and floodplain change or departure from the reference condition given the types and extent of channel, floodplain, and land use modifications documented in the watershed;
   - **Channel Adjustment Process,** or type of change that may be underway in the stream channel (e.g., vertical, lateral, or channel planform adjustment processes) due to natural causes or human activity that may result in a change to the valley, floodplain, and/or channel; and
   - **Reach Sensitivity** of the valley, floodplain, and/or channel to change due to natural causes and/or human activity.

   These assessment parameters are useful in evaluating the current and future conditions of:
   - **stream and riparian habitat, and**
   - **erosion and flood hazards**.

   The Provisional Geomorphic Condition Evaluation is an appropriate tool for setting priorities and problem solving in a watershed context because it will not only tell you the proximity of adjusting

reaches to one another, but you will be able to ascertain how one reach may be affecting the condition of another. If you or someone in your team does not have experience with predicting the channel adjustment processes and conditions that follow in response to channel and floodplain modifications you may want to put the Provisional Geomorphic Condition Evaluation (Step 9) aside until you have spent more time in the field completing Phase 2 and/or Phase 3 assessments. If you opt for going to the field first, it is highly recommended that you revise the provisional condition evaluations in the Phase 1 DMS before setting priorities for protection, management, or restoration projects. An interim way to set priorities within your watershed is provided through the completion of a Stream Impact Rating. The River Management Program has developed guidance for basin planners on reach prioritization that places a high priority on identifying reference-condition reaches for protection and red-flagging "strategic sites" where certain channel adjustments may be occurring that would cause significant landowner conflicts.

4. A **Like Reach Evaluation** that groups the reaches in your watershed assessment by similar valley and stream types and similar geomorphic condition or impact rating (Step 10). Grouping streams by like reaches is useful in selecting a manageable number of reaches on which to conduct the Phase 2 and Phase 3 field assessments. By collecting detailed information on reaches that represent the different reach types in your watershed you are better able to characterize the entire watershed without conducting extensive and time-consuming field surveys on the entire watershed. The information collected on the representative reaches can be used to understand the other "like" reaches in the watershed.

5. **Watershed Maps,** including USGS maps where your assessment team has made field notations during the watershed orientation and windshield surveys, and computer generated GIS watershed maps depicting Phase 1 reaches and data, the provisional geomorphic condition, and the like reach evaluation.

## Basic Methods and Skills

**Data Sources**

The information collected in a Watershed Assessment comes from three primary sources: remote sensing, existing data, and windshield surveys, as defined below. The type of information source used to evaluate a parameter is listed next to each parameter in the Handbook.

1) **Remote Sensing Data** includes data collected from maps, aerial photographs, and orthophotos.

2) **Existing Data** includes, but is not limited to, studies such as NRCS soil surveys, and information, such as dam locations, available from the Vermont Agency of Natural Resources. Other useful existing data, such as the regional hydraulic geometry curves, are included in the Appendices. Existing data may also include first-hand knowledge from resource specialists.

3) **Windshield Survey Data** includes general observations made from a car as you drive about the watershed. These observations will help you verify information interpreted from maps and aerial photos. Please be careful when gathering data from a car. **You need at least two people for this exercise: one to drive and one to record observations.**

**Using The GIS Stream Geomorphic Assessment Tool (SGAT)**

To support the Phase 1 Watershed Assessment, the Vermont Agency of Natural Resources (ANR) has developed a GIS extension for ArcView called the Stream Geomorphic Assessment Tool (**SGAT)**. Use of GIS and the SGAT program significantly streamlines many of the Phase 1 calculations and measurements. The SGAT program automatically populates dBase tables that can be imported into the Phase 1 DMS. The extension is set up in a user friendly interface format; however, it is expected that the user has a basic understanding of ArcView. Currently SGAT is designed to work with ArcView 3.x.

**Evaluation with SGAT:**
Throughout the Phase 1 handbook, the term "SGAT" appears in parentheses after each Step # (parameter) for which SGAT can be used to generate data.

A separate handbook has been written to support the use of SGAT (contact the DEC River Management Program). It is recommended that a new user read through the SGAT handbook before using the tool in order to understand how the GIS extension works and which assessment steps can be completed or facilitated by the program. The SGAT user handbook and the extension tool can be obtained on computer CD from the DEC River Management Program.

**Using the SGAT Feature Indexing Tool (FIT)**
Evaluation of some of these parameters requires identification and measurement of physical features or characteristics such as bank armoring, channel straightening and locations of berms and roads in the corridor. Using the SGAT Feature Indexing Tool (FIT) provides an efficient means for documenting and measuring features of interest. Use of the FIT also results in a data base file that can be imported into the Phase 1 DMS, thus eliminating the need to manually enter the data. Instructions on acquiring and using the FIT are contained in the SGAT manual.

**Evaluation with FIT:**
Throughout the Phase 1 handbook, the term "FIT" appears in parentheses after each Step # (parameter) for which the FIT can be used to generate data.

The Feature Indexing Tool (FIT) should be used to document the following impacts to a stream during the Phase I (and updated in Phase 2) Assessments:

| Phase 1 | Phase 2 | Shape Type | Impact | Sub-Impact | Location | Option 1 | Option 2 |
|---|---|---|---|---|---|---|---|
| 3.1 | 1.2 | Point | Alluvial Fan | N/A | N/A | N/A | N/A |
| 5.3 | 3.1 | Polyline | Bank Armoring or Revetment | Rip-Rap<br>Hard Bank<br>Other | Right Bank<br>Left Bank | | |
| N/A | 4.9 | Point | Beaver Dam | N/A | N/A | Length Affected | |
| 5.2 | 4.8 | Point | Bridge and Culvert | Bridge<br>Culvert<br>Unknown | N/A | Length Affected | |
| 4.3 | 3.2 | Polyline | Buffer Less than 25 feet | N/A | Right Bank<br>Left Bank | | |
| N/A | 2.x | Point | Cross Section Location | NOT Representative<br>Representative | N/A | Number | |
| N/A | 4.4 | Point | Debris Jam | N/A | N/A | | |
| 6.2 | 1.3 | Polyline | Development | N/A | Both Sides<br>One Side | | |
| 5.5 | 5.5 | Polyline | Dredging | Commercial Mining<br>Dredging<br>Gravel Mining | Exact Location<br>General Location | | |
| 6.1 | 1.3 | Polyline | Encroachment | Berm<br>Improved Path<br>Railroad<br>Road | Both Sides<br>One Side | Height | |
| 7.2 | 3.1 | Polyline | Erosion | N/A | Left Bank<br>Rigth Bank | Height | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5.1 | 4.5 | Point | Flow Regulation and Water Withdrawal | Large Bypass<br>Large Run of River<br>Large Store and Release Large Withdrawal Small Bypass<br>Small Run of River<br>Small Store and Release Small Withdrawal | Drinking<br>Flood Control<br>Hydro-electric<br>Other<br>Recreation | | |
| 3.2 | 1.6 | Point | Grade Control | Dam<br>Ledge<br>Waterfall<br>Weir | Picture<br>NO Picture | Height Above Water | Total Height |
| N/A | 3.1 | Point | Gully | N/A | N/A | Height | |
| N/A | 3.1 | Polyline | Mass Failure | N/A | Left Bank<br>Right Bank | Height | |
| 6.4 | 5.2 | Point | Migration | Avulsion<br>Braiding<br>Flood Chute<br>Neck Cutoff | | | |
| N/A | 5.3 | Point | Steep Riffle or Head Cut | Head Cut<br>Steep Riffle | | | |
| N/A | 4.7 | Point | Storm Water Input | Field Ditch<br>Other<br>Overland Flow<br>Road Ditch<br>Tile Drain<br>Urban Storm Water Pipe | | | |
| 5.4 | 5.5 | Polyline | Straightening | Straightening<br>With Windrowing | | | |
| N/A | 5.4 | Point | Stream Crossing | Animal Crossing<br>Stream Ford | | | |

N/A = Not Applicable

**Using the Web Based Data Management System (DMS)**

Vermont ANR has also developed a web based data management system (DMS). The DMS can be used to automatically upload the SGAT & FIT data (stream characteristics, soils, land use data & indexed features) and for manually entering Phase 1 information from data sheets. The DMS also has the following capabilities:

- Built in QA checks to assure data accuracy and consistency between phases of assessment
- Built in reports that simulate the standard reports in Appendix A, as well as other reports that may be of interest
- The ability to export all of the Phase I data in the .dbf format to be used in mapping or other database applications
- Automated upload of both SGAT and FIT data

**Remote Sensing Skills**

The following remote sensing skills will be needed to complete the Phase 1 Watershed Assessment are:

- Reading topographic maps
- Interpreting aerial/orthophotos
- Calculating some basic mathematical equations (examples are provided in the text)
- Reading soil and geologic surveys
- Use of ArcView 3.X mapping software and extensions

These skills are easily learned with some training. If you are assembling a team of people to complete a Watershed Assessment it is very important to involve someone who has experience reading maps and aerial/orthophotos to assist you. The involvement and technical assistance of specialists in the fields of ge-

ology, aquatic ecology, and fluvial geomorphology is also highly recommended. Contact the DEC River Management Program, the Vermont Fish and Wildlife Department, or the Vermont Geological Survey about the availability of professionals in these fields and/or to learn about opportunities and requirements for technical training to complete Phase 1 Assessments.

**Reminder**
The right bank and left bank of a channel are defined looking downstream. If you have any questions about the definitions of any terms, please refer to the glossary in Appendix Q.

## Materials Needed

You will need the following materials to complete the watershed assessment:

- A copy of the topographic maps covering your watershed
- Orthophoto series; two different time periods (most recent and a series from at least 20 years ago)
- Computer mapping program that can measure distances, areas, and latitude/longitude,
- Consistent access to the internet (the ANR data management system is web based)

Materials needed for using SGAT & FIT:

- Arc View 3.1, 3.2 or 3.3
- Most recent version of the SGAT extension and accompanying user handbook (Version 4.56 or above)
- Digital topographic maps
- Digital orthophotos
- GIS layers for streams (1:5000 VHD)
- Manually digitized watersheds, meander center lines, valley walls
- Digital NRCS soils, and 2002 land use theme (lclu)
- GIS computer tools or computer mapping programs are commercially available and are very useful tools for measuring slopes, distances, and other assessment parameters; however, these tools are not required to complete a Phase 1 assessment.

Published data resources are listed throughout this Handbook. Below is a summary table of sources for acquiring topographic maps, orthophotos, and similar basic data sources. Many helpful data layers are available as GIS coverages from the Vermont Center for Geographic Information (VCGI). Check their website at www.vcgi.org.

| **Materials** | **Source** | **Phone** |
|---|---|---|
| Vermont Hydrography Dataset | Vermont Center for Geographic Information (VCGI) at http://www.vcgi.org | (802) 882-3000 |
| Topographic maps | Retail outlets and Vermont Geological Survey | (802) 241-3608 |
| Orthophotos | Vermont Mapping Program (VT Dept. of Taxes) http://www.state.vt.us/tax/vermontmapping.htm | (802) 241-3552 |
| Surficial geologic map | Vermont Geological Survey | (802) 241-3608 |
| FEMA National Flood Insurance Program (NFIP) maps | Town Clerks, Dept. of Emergency Management, DEC Division of Water Quality | (802) 241-3770 |
| Soil Surveys | Natural Resources Conservation Service (NRCS) | (802) 951-6796 |
| Wetland maps | DEC Division of Water Quality | (802) 241-3770 |

## Getting Started

**Read the Handbooks**
Each member of your assessment team should read the Phase 1 Handbook before getting started. The team member(s) running SGAT should read the SGAT manual. Understanding the entire protocol and the rationale behind it can save a lot of questions that will undoubtedly arise otherwise.

**Contact the ANR**
It is *IMPERATIVE* that you set up a project-scoping meeting with the DEC River Management Program before beginning an assessment. This offers several advantages: finding out whether there have been updates of the protocols; receive a login so data can be uploaded and entered into the DMS; receiving information on Phase 1 assessment training opportunities; receiving data quality assurance (QA) assistance; and learning about other assessments that may have occurred or are currently underway in your study area.

> ***It is critical that you contact ANR to find out about other assessments in your watershed, as you need to coordinate your reach numbering assignments with prior assessments completed upstream or downstream from where you plan to work.***

**Have a Scoping Meeting**
Before starting your project, the various constituents involved in the project should get together to be sure the goals of the project are understood. It is also a good time to review the steps of the process, and if there are multiple partners collecting data that each person understands their part in the project. A "Phase 1 Task Register" table (Appendix A) can be used to assist in this process.

**Protocol Steps**
Watershed characteristics evaluated as a part of this assessment protocol are referred to as "parameters" and have been organized under seven assessment "steps." For example a protocol for measuring watershed size is found in Step 2.7 (the seventh parameter evaluated in Step 2).

**Data Sheets**
Paper data sheets (Appendix A) are organized by step and parameter number and have a heading to record the following information:

- ***Stream Name:*** The name of the stream or river printed on the USGS topographic map. For unnamed tributaries, use the tributary numbering system outlined in Step 1 of these protocols.
- ***Sub-watershed*****:** It is also helpful to note the name of the receiving water in parentheses. Subwatersheds are generally at the scale of 16 sq.mls. to 63 sq.mls. (National Hydraulic Unit Code - 10 Scale). Watershed delineations showing the 8 and 10 Scale Hydraulic Units and their codes are available as GIS data layers from the Vermont Center for Geographic Information (VCGI) at www.vcgi.org.
- ***Watershed*****:** The name of the main river or lake at the downstream endpoint of your watershed. Watersheds are generally at a scale greater than 63 $mi^2$. (Hydraulic Unit Code - 8 Scale).
- ***U.S.G.S. Map Name*****:** USGS map name(s) on which the watershed is located. Map names are usually located in the bottom right hand corner of the maps.
- ***Observers:*** Name of observer(s) completing the assessment.
- ***Organization/Agency*****:** Three (or more)-letter acronym(s) of the organizations and agencies represented in the assessment crew.

**Paper Records**
You are encouraged to use both the hard paper copy data sheets and DMS report forms to catalogue and store assessment data for all data that is manually collected. **It is not necessary to keep hard copies of data that is collected in SGAT or the FITsince you will have a digital backup of the data.**

**The following parameters are evaluated in SGAT and therefore do NOT need to be recorded on the paper data sheets:**

Town
Ortho Photo
Topographic Map
HUC 10
Reach Number
Latitude & Longitude
Northing & Easting
Upstream & Downstream Elevations
Valley Length
Channel Length
Valley Width
Watershed Size
Geologic Material (Dominant % and Subdominant %)
Hydrologic Group and %
Flooding and %
Water Table and % (shallow and deep)
Erodibility and %
Current dominant and Subdominant Land Cover in the Watershed – including % urban and % crop in the Watershed
Current dominant and Subdominant Land Cover in the Corridor – including % urban and % crop in the Corridor

Ideally, data sheets are accompanied with paper maps. These base maps will likely be USGS topographic maps, but if you are using GIS you can create your own base maps that contain topography and other useful data layers you may have available. Be sure to include basic information on the map, such as the watershed boundary, the beginnings and ends of each stream reach, and any watershed orientation and windshield survey field notes. Step 7 gives a description of the map notation used in windshield surveys.

**Computer Tools & Outputs**

Use the DMS to store and manage your assessment data. Appendix B offers guidance on how to use the Phase 1 DMS and provides examples of these forms and data queries used to complete Phase 1 products.

Entering the Phase I Geomorphic data into the web based DMS to the DEC River Management Program to include in the state geomorphic dataset provides the following benefits:

- ensuring that a duplicate copy of the data exists in an alternate location;
- Automated QA reviews to check for data consistency and accuracy;
- building a statewide dataset that will result in a more powerful problem solving tool; and
- receiving assistance from other geomorphic assessment professionals in data interpretation.

## Phase 1 Quality Assurance Program

At the start of your Phase 1 assessment establish a QA team that includes the primary data collector(s). This team will be responsible for reviewing the data collected. Members of this team need to be trained in the protocols and use of the Phase 1 DMS, and at least one member of the team should be trained in quality assurance techniques. Training can be obtained from the DEC River Management Program (RMP).

Once data has been collected and entered into the DMS, the standard reports and tables in the DMS can be generated and reviewed by the QA team. The team can determine if there is information that is missing, inconsistent with the protocols, or needs further evaluation. Data that raises concerns or problems can then be assessed and the method of correcting or completing the information can be established. A good first check to ensure data accuracy and completeness is to compare the original data sheets filled out by hand to those generated by the DMS. Though tedious, comparing each data entry line for line will ensure there are no errors resulting from simple "typos" and improper transfers of data from the raw data sheets to the DMS.

Many Phase 1 parameters are assessed in the field during Phase 2 and Phase 3 Stream Geomorphic Assessments. If you have confirmed or changed remote sensing data in the Phase 1 DMS as a result of **reach scale** field assessments, the meta data (see below) needs to be changed. **It is very important that you do not characterize an entire reach in the Phase 1 DMS based on a field assessment of only a segment or part of the reach. Wait until you have field assessed the entire reach before revising the Phase 1 data.**

Revising the Phase 1 DMS with new and/or field verified data may strengthen the use of the data in watershed analysis. After you make these revisions it is essential to document the changes. This should be done by updating the meta data reach by reach, parameter by parameter to ensure that you preserve the ability to pull out certain types of data (i.e., remote sensing versus field verified data).

Everyone who attempts to use your Phase 1 data will appreciate the efforts made to document its quality, including its deficiencies. If you encounter problems with incomplete data for certain parameters, select "Not Evaluated" for that reach and parameter and make a note in the comments box.

Before beginning a Phase 1 assessment read the QA protocol at the end of the Phase 1 Handbook to more fully understand the data documentation process. After the Phase 1 assessment steps are completed, the QA sheet and QA data entry form in the DMS (Appendices A and B) should be completed. The QA sheet is a set of questions that documents which steps were completed and when; what assessment tools and data sources were used; the level of training received by members of the assessment team; and the confidence level of the assessors towards the data collected at each assessment step. These QA sheets should be reviewed and finalized by the QA team. When data is updated or changed, the same process of data review should to be completed. The QA sheet can then be updated to indicate the change in data.

The portions of the QA sheet completed by the assessor will assist in incorporating the data into the State Geomorphic DMS (see Appendix P). As the data is brought into the State DMS, ANR staff will review the data, and the QA process (and QA sheet) will be completed. This ANR-level QA process will be done each time data is updated or changed and resubmitted to ANR.

## Phase 1 Meta Data Description

Metadata is used to document the methods and sources used in collecting geomorphic assessment data. The RMP has developed a list of standard metadata options for each of the Phase 1 parameters. Meta data should be documented on the data form provided in Appendix A. The documentation of the metadata is completed during the automated upload of the SGAT and RIT data as well as during the manual data entry task in the DMS where the user will find a drop-down menu listing the options for each parameter. The default for each parameter is the data collection method most commonly used. If you did not use the default method you must manually change the metadata for each applicable reach in the DMS.

If you find that none of the metadata options for a parameter adequately describes the method you used please contact the RMP staff.

## Menu Options – No Data versus None versus Not Evaluated:

In order to qualify the completeness and accuracy of a data set the following options are included for most of the Phase I menu options:

| | |
|---|---|
| **No Data** | No data sources are available to determine if the impact exists. A selection of "No Data" indicates that the data collector has exhausted all options for obtaining the data (as described by the meta data) and has found that no sources are available to determine if the impact exists. |
| **None** | A selection of none indicates the data collector reviewed all available options for obtaining data (as described by the meta data) and found that the impact is not documented anywhere. A selection of "None" indicates that at the Phase I remote sensing assessment level no evidence of the impact can be found. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. Further work should be completed. |

Example:
If you are collecting data for step 6.3, Depositional Features and in reviewing the 1:5000 ortho photos you find that you can't see the stream well enough to determine if any depositional features exist select the "no data" option because you can't tell if the impact exists.

However, if you are collecting data for Step 5.5, Dredging and Gravel Mining, and you have interviewed the DEC, NRCS and town officials and locals and have found no existing evidence of dredging or gravel mining you should select "None" because you have exhausted all reasonable Phase I data sources and have found no evidence of the impact.

**It is important to understand the difference between none, no data and not evaluated prior to beginning a Phase I Geomorphic Assessment. Please use these options where applicable.**

## Starting the Phase 1 Assessment – Defining Stream Reaches

To start the Phase 1 assessment you must first do the following:

1. Delineate the primary watershed
2. Select streams within the watershed to be assessed
3. Visually define a "first cut" of geomorphic reaches for the assessment streams using the ground rules and guidance provided in this section
4. Number reaches according to the numbering systems outlined in this section
5. Conduct a watershed orientation to verify reach delineations and to calibrate your eye as to how features on the maps and orthophotos, which you will be using to complete the Phase 1 assessment, appear on the ground.

**1. Delineating the Primary Watershed**

Detailed instructions on how to delineate watershed boundaries and how to read topographic maps are provided in Appendix D.

Determine the boundary of the watershed that encompasses the stream(s) you are interested in assessing. This is considered the "primary watershed", and includes all the land area that contributes flow to the assessment stream(s). Draw this watershed boundary on USGS topographic maps, as described in detail in Appendix D. Refer to the SGAT User Manual on how to develop a digital watershed data layer.

**2. Selecting Assessment Streams**

Once you have determined the primary watershed you are going to assess, you need to identify what sections of stream within the watershed you will complete the Phase 1. It is helpful to delineate the boundaries of the sub-watersheds for each major tributary to gain an understanding of what percentage of the watershed those tributaries comprise. Your assessment goals, local priorities and available resources should be considered when deciding how many tributaries to evaluate in the watershed. If resources are limiting, you can delay conducting steps 1 through 10 of the assessment for some tributaries, but you should define and number reaches for all of the mainstem and the tributaries that you plan to include in the assessment over the long run.

**3. Defining Geomorphic Stream Reaches – A Visual "First Cut"**

Next, for those streams you have selected for assessment, define geomorphic stream reaches based on the geomorphic characteristics of stream size, valley characteristics, and to some extent, underlying geology as described below. Specifically, you will be looking at stream confinement (valley width compared to stream width), valley slope, geologic materials, and tributary influence to determine distinct geomorphic stream reaches within the watershed.

***Background***

On the broadest level, streams are classified by the shapes of the valleys in which they flow: steep and confined; moderately steep and narrow; or gentle sloped and broad. Figure 1.1 below shows the different valley types and the typical changes in sediment regime characteristics (source, transfer, and response) and water discharge as a function of drainage area.

In general, these valley types have different physical characteristics. As you travel from steeper to gentler sloped valley segments, the bed material transitions from larger boulders and cobbles to finer sands and gravel. The amount of sediment deposited in the channel increases as the slope of the channel decreases. Typically, steeper headwater streams flow in relatively straight channels through narrow valleys. The streams are confined in the valleys. As the water moves downstream, valleys generally become wider and

the slopes become gentler. Streams begin to wind around more, becoming more sinuous, with gentle channel gradients and finer bed materials.

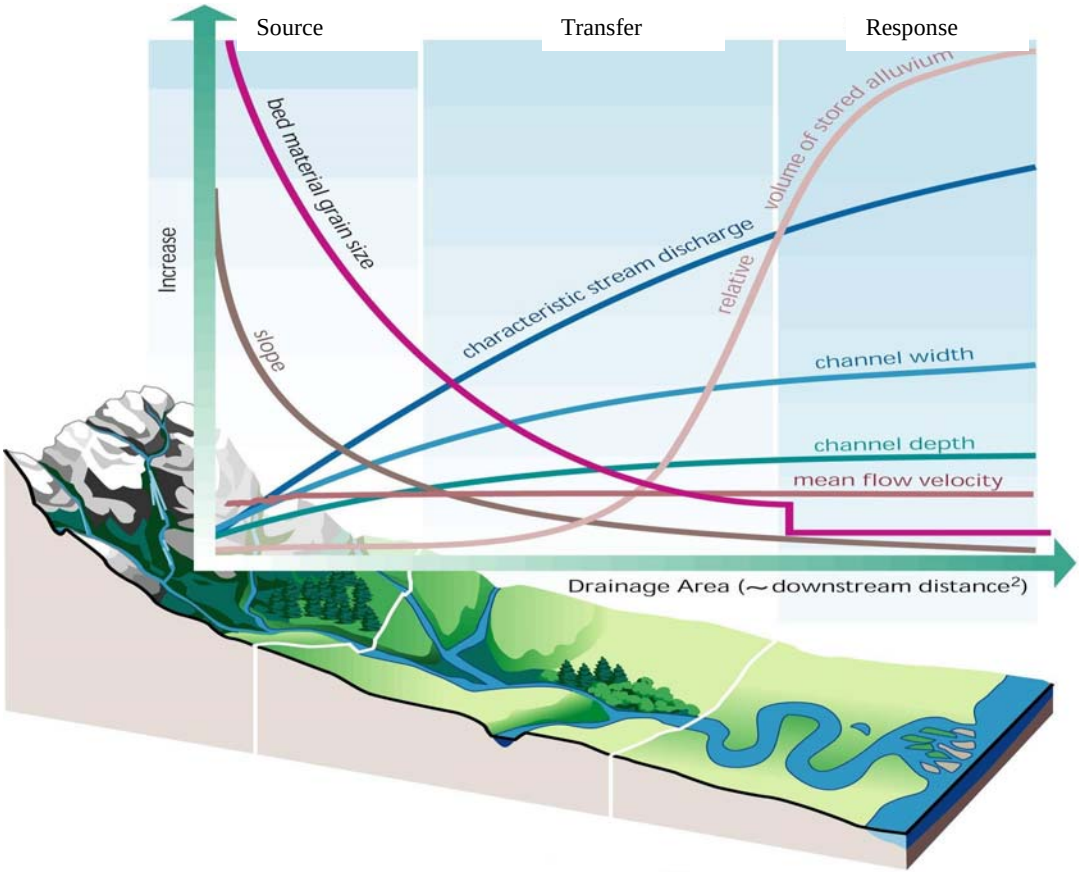


**Figure 1.1** Confined, narrow, and broad valley types (from the Stream Corridor Restoration Manual, Federal Interagency Stream Restoration Working Group, 1998).

With these valley types in mind take a first cut at defining reaches based on the following reach defining characteristics, generally listed in order of priority: **stream confinement (or valley width), valley slope, geologic materials, and tributary influence** (described below).

***Evaluation***

Use the USGS 1:24,000 topographic maps overlain with the Vermont Hydrography Dataset (VHD) 1:5,000 stream layer to do this evaluation. There are no measurements taken during this first cut of defining reaches. It is based solely on the visual differences you observe on the maps for the reach-defining characteristics.

Before you formally label the map with the reach numbers, complete the Watershed Orientation (described at the end of this section) and Step 2 to see if any of your reach determinations will need to be refined. You may decide as you start measuring the various parameters in Step 2 that some reaches should be combined or separated. If you are using SGAT, however, which automates most of the Step 2 measurements, you will likely not want to change reach breaks once you have digitized sub-watersheds for these reaches. Be sure to give careful thought to your reach breaks and use the Watershed Orientation to quickly verify them in the field. The Watershed Orientation is particularly helpful in identifying valley walls and in understanding valley slope and confinement.

By the end of Step 2, you will have assigned each reach a "reference stream type" classification (as defined in the Program Introduction). The following discussion offers general guidelines for determining reach breaks and evaluating valley form, geology, and tributary influence to define distinct geomorphic stream reaches.

***Ground Rules for Defining Reaches:*** Stream reaches designate a length of channel based on reference stream type characteristics that can be distinguished in some way from the reaches immediately upstream or downstream. You are encouraged to verify initial reach breaks in the field during the Watershed Orientation to see if your visual "first cut" of reaches makes sense on the ground. During Phase 2 and Phase 3 field assessments, additional stream type characteristics beyond the Phase 1 parameters of stream size, geology, valley confinement and valley slope, may influence where you decide to make reach breaks, either dividing or combining reaches based on your field observations and measurements. For reach breaks defined later in the assessment process (i.e., during Phase 2 or Phase 3) there is a "sub-reach" numbering and tracking system provided to allow for this later distinction of reaches without having to renumber and reassess Phase 1 reaches. See the Phase 2 Handbook Introduction for guidance on numbering sub-reaches.

- Choose one person to review all the reaches visually defined in your watershed in order to ensure consistency between different assessors' reach designations.
- Start defining reaches from downstream to upstream on the mainstem first and then determine the reaches on the major tributaries (again downstream to upstream).
- When a large tributary enters the mainstem, this defines a new reach on the mainstem **just above** the confluence of the tributary. (See discussion under "tributary influence" later in this section.)
- Consider creating reach breaks on the upstream and downstream ends of large alluvial fans (see Step 3.1 on alluvial fans) due to the sensitivity of these streams to both vertical and lateral adjustment.
- Consider creating reach breaks on the upstream and downstream ends of large impoundments that have changed the general shape and fluvial processes of the stream or river. Impoundments that warrant their own reach are those that are substantially wider than the natural channel. In addition, the dams creating these impoundments are typically constructed on natural grade controls (i.e., bedrock), which influence vertical channel adjustments. Small riverine impoundments may not warrant reach breaks. Though Phase 1 reaches are intended to represent reference conditions, large impoundments are a necessary exception to this rule, as they are often too modified to determine reference valley confinement and slope, thus the reason for breaking them out as their own reaches.

***Evaluating Stream Confinement (valley width):*** Reach breaks are often made where the valley width changes. Valley width is important because it is an indicator of how confined the stream is and whether it will have access to a floodplain at different flood levels. To determine valley width differences look for relative changes in the distance between toes of opposing valley walls. The toe of a valley wall can be identified as the bottom of the more steeply sloped portion of the valley. This is evident on a topographic map as the place where the contour lines change from being widely spaced (on the gentle sloped valley floor) to being more closely

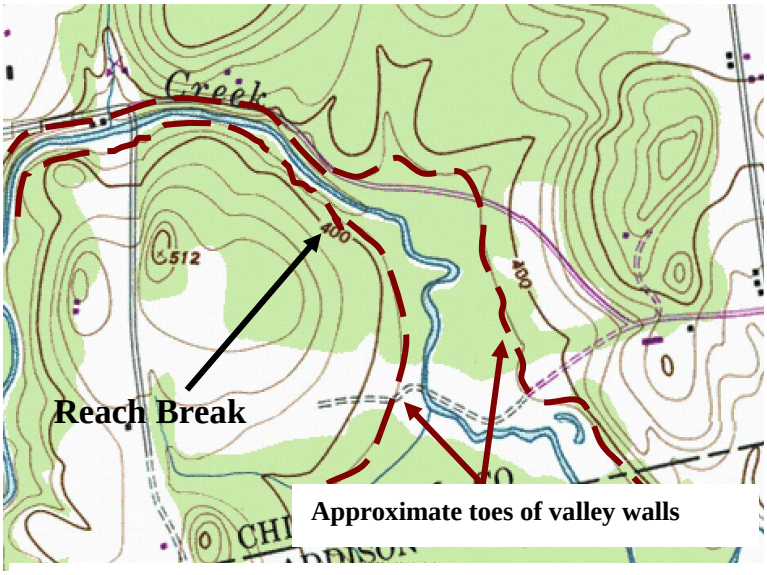


**Figure 1.2** Reach break based on a change in the valley width.

spaced (on the steep valley wall). A significant change in the confinement of the stream, for example where a wide valley transitions to a narrow valley, is usually a good place to make a reach break (Figure 1.2). There may be small sections of valley that are somewhat narrower or wider than the average valley width for a given stretch of stream. If the section is less than a ¼ mile long it may not be necessary to break it out as its own reach, but rather to "lump it" within the larger section of stream. Use your judgment. If the section is significantly narrower or wider, make a reach break no matter how long the resulting reach is.

***Evaluating Valley Slope:*** Another important valley characteristic to consider when defining reaches is the slope of the valley. To visualize the valley slope look at the distance between contour lines that cross the stream and valley floor. Widely spaced contour lines indicate a gentle slope and tightly spaced contour lines indicate a steeper slope. Make reach breaks where there is a substantial change in the valley slope. If there is only a short section of valley, less than ¼ mile, which has a different slope than the rest of the valley, it may not be necessary to break out that section as its own reach.

**Table 1.1** Guide to valley slopes in defining "first cut" stream reaches.

| Percent Slope | Description of slope | Approximate contour interval spacing on 1:24,000 map |
|---|---|---|
| > 4% | Very Steep | <0.2 in. |
| 2-4% | Steep | ~0.2 - 0.5 in. |
| 0.5-2% | Moderate | >0.5 in. |
| <0.5% | Gentle | >1 in. |

Another indication of valley slope and confinement is channel sinuosity, which is a ratio of channel length to valley length. Changes in channel sinuosity can be determined on topographic maps. Generally, channels in steep, confined valleys have low sinuosity, and channels in broad, gentle-sloped valleys have high sinuosity. Reach breaks may be appropriate where there is a significant change in valley slope and confinement as indicated by a channel's sinuosity (Figure 1.3). Caution is recommended, however, in using sinuosity as the basis for making a reach break, especially in those situations where the straightness of the channel may be explained by changes in land use or modifications to the channel, valley or floodplain. Do not make a separate reach for a section of a stream within a valley of similar characteristics based solely on a change in the channel sinuosity. If, for instance a high sinuosity stream within a broad, gentle-sloped valley becomes straight (low sinuosity) for a short distance and then becomes sinuous again, do not create a separate reach if the straighter section cannot be explained by differences in local soils and/or geology (as determined in Step 3).

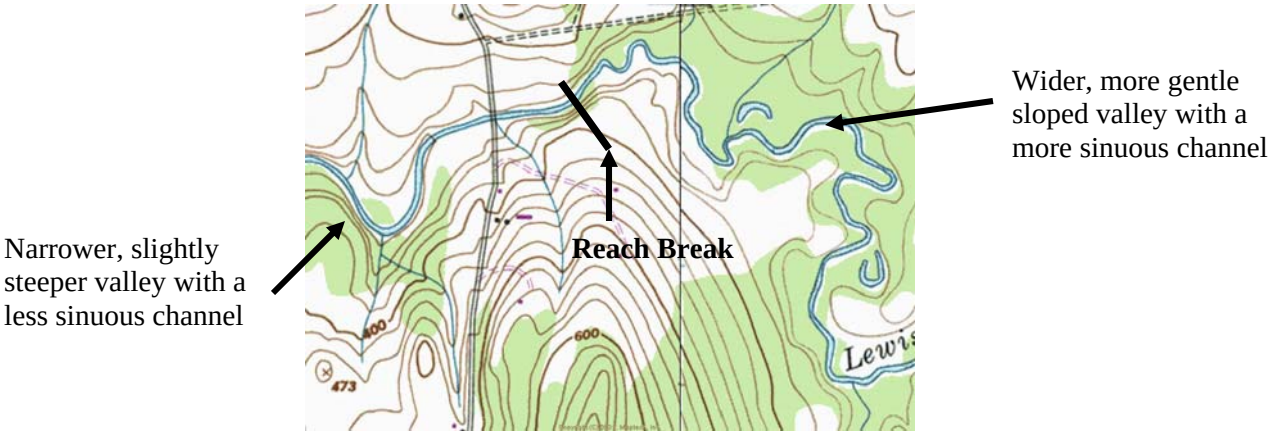
Wider, more gentle sloped valley with a more sinuous channel
Narrower, slightly steeper valley with a less sinuous channel
Reach Break
600
600
473

**Figure 1.3** Reach break due to a change in valley slope and confinement as indicated by a change in the channel sinuosity.

***Evaluating Geologic Materials:*** A major change in the erodibility of soils or geologic materials along the stream may justify a reach break. If you are familiar with evaluating the characteristics of soils and surficial geologic materials, you may want to consider using this type of information in determining reach breaks. This data can be found on NRCS soil survey maps available through NRCS and surficial geologic maps available through the Vermont Geological Survey. To determine if there are any significant geologic changes within your watershed, find the streams and rivers of interest on the soils and surficial geologic maps, and note any major changes in the surficial materials' characteristics, particularly erodibility. Consider these locations as possible reach breaks. Be sure to read about geologic materials in Step 3 of this Handbook and Appendix F before finalizing your reach breaks.

***Evaluating Tributary Influence:*** The confluence of **major** tributaries is a place to consider making a reach break on the mainstem stream receiving the tributary. **Major tributaries are those that constitute 10 % or more of the primary watershed area at their confluence with the mainstem**. Delineating the watersheds of major tributaries within the primary watershed will help you identify where to make reach breaks on the mainstem based on tributary watershed size. Break the mainstem reach just above the confluence of the major tributary. This same rule applies when breaking reaches on the tributaries themselves – consider the influence of **minor** tributaries (those that feed major tributaries).

In the interest of practicality, as you begin making reach breaks in the headwaters of the watershed, you may choose to discontinue using tributary influence to determine reach breaks. In headwater areas the mainstem typically becomes a steeper, more confined channel of similar stream type throughout. Often numerous tributaries of similar watershed size come together over a short distance to make up the main channel. In these cases, you may choose to consider all of these as **minor** tributaries together, and perhaps only break a reach on the mainstem upstream of a group of confluences of these tributaries, rather than at each one.

**4. Reach Numbering**

Reach numbering is necessary to efficiently organize, track, and communicate reach-related data. The following objectives are also met by the reach numbering conventions described below:

- The ability to discern where a reach is located within its watershed and to be able to query for data upstream of a reach, provided by the **hydrologic number**; and
- The ability to link stream geomorphic and physical habitat data with other water resource data that has been stored electronically in other State databases, by including fields for those databases' record identifiers, such as the Vermont Waterbody ID.

Though the numbering system described below is a bit complex, this provides the flexibility needed to permit users to conduct watershed assessments at different scales, at different levels of detail, and at different times, and still be able to mesh assessment data together into a single statewide database.

***Hydrologic Number:*** The hydrologic number is an alpha-numeric identifier that describes where a reach is located within the watershed drainage network. This number, combined with a unique project code assigned by the Data Management System, creates unique reach identifiers for reaches from different watershed assessments. This numbering system indicates into which reach a tributary enters, allowing one to evaluate the upstream watershed inputs to a reach through database queries that sort by reach number. It also provides the information needed to locate a reach within the watershed. The SGAT program facilitates the assignment of reach hydrologic numbers. See the SGAT User Manual for details.

The following numbering conventions are used to assign reach hydrologic numbers:

- **R#** designates reaches on the mainstem of select large streams within the state of Vermont (see list below). These reaches are numbered sequentially from downstream to upstream as R01, R02, R03,

etc. Rivers that should be labeled with R for the mainstem include the White, Missisquoi, Lamoille, Winooski, Otter, Ompompanoosuc, Ottauquechee and the Passumpsic. If your assessment area is located within one of the watersheds listed above please contact the River Management section for further detail on how to number the reaches appropriately.

- **M#** designates reaches on the mainstem of the remaining HUC 10 size streams (those not listed above), which are numbered sequentially from downstream to upstream as M01, M02, M03…etc (Figure 1.4).

- **M#T#** or **R#T#** designates **major** tributaries on the mainstem, those that drain 10% or more of the watershed area at their point of confluence with the mainstem. These major tributaries are numbered sequentially from downstream to upstream along the mainstem as T1, T2, T3… etc. They are preceded by the M# (or R#) that designates the mainstem reach into which they flow. Individual reaches on each tributary are designated with a period and number following the tributary number (e.g., T3.01 is assigned to the first reach on the third major tributary up the mainstem).

- **M#S# or R#S#** designates **minor** tributaries to the mainstem river, those comprising less than 10% of the watershed at their confluence with the mainstem (e.g., M02S2 is assigned to the second minor tributary on the mainstem that flows into mainstem reach M02). Minor tributaries are numbered sequentially from downstream to upstream; however, the S# sequence starts over for each mainstem reach (Figure 1.5). For example, the first two minor tributaries entering into the mainstem reach M01 would be M01S1 and M01S2, and the first two minor tributaries entering into reach M02 would be M02S1 and M02S2. Individual reaches on each minor tributary are designated with a period and a number following the tributary number (e.g. M01S3.4 is assigned to the fourth reach of the third minor tributary that enters the first reach of the mainstem).

- **M#T#S# or R#T#S#** designates **minor** tributaries to the major tributaries. Additional "S" letters are added as needed to designate tributaries of tributaries of tributaries, etc. Individual reaches on minor tributaries are designated with a period and number following the tributary number. For example, M03T1.02S1.04 represents the fourth reach of the first tributary that flows into the second reach of the first major tributary, which flows into the third reach of the mainstem.

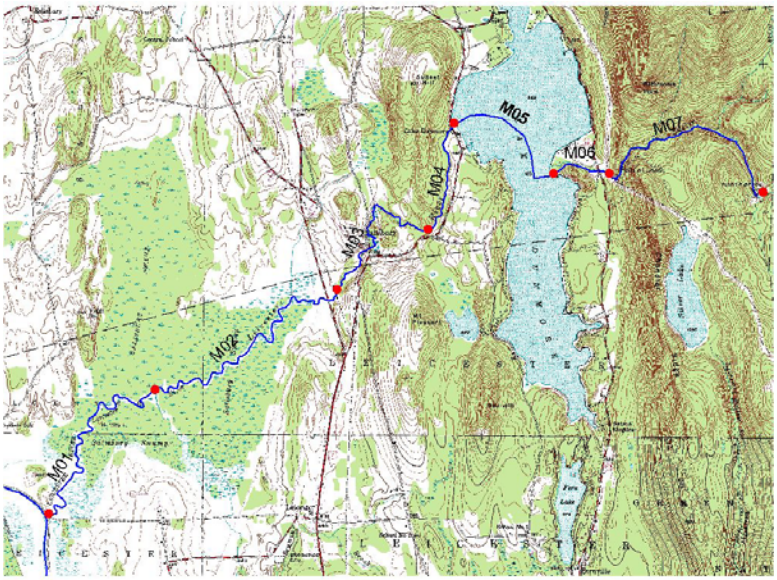


**Figure 1.4** The impounded segment of stream is assigned a reach number using the SGAT ArcView extension. The reach is excluded from further geomorphic assessment in the DMS using the "exclude" option.

When starting the assessment it is essential to determine all mainstem reaches and to label at least all the major and minor tributaries to the mainstem (M#T# and M#S#) before starting to collect other data. Even if you plan to complete a Phase 1 assessment over several iterations, you should label all mainstem tributaries on the topographic maps up front to ensure that you have included all major tributaries in your numbering system. This will avoid reach numbering errors in future assessment work, preserving the capability to sort the watershed data hydrologically from downstream to upstream according to the drainage pattern. If you need assistance on where to start the numbering process contact the DEC River Management Program.

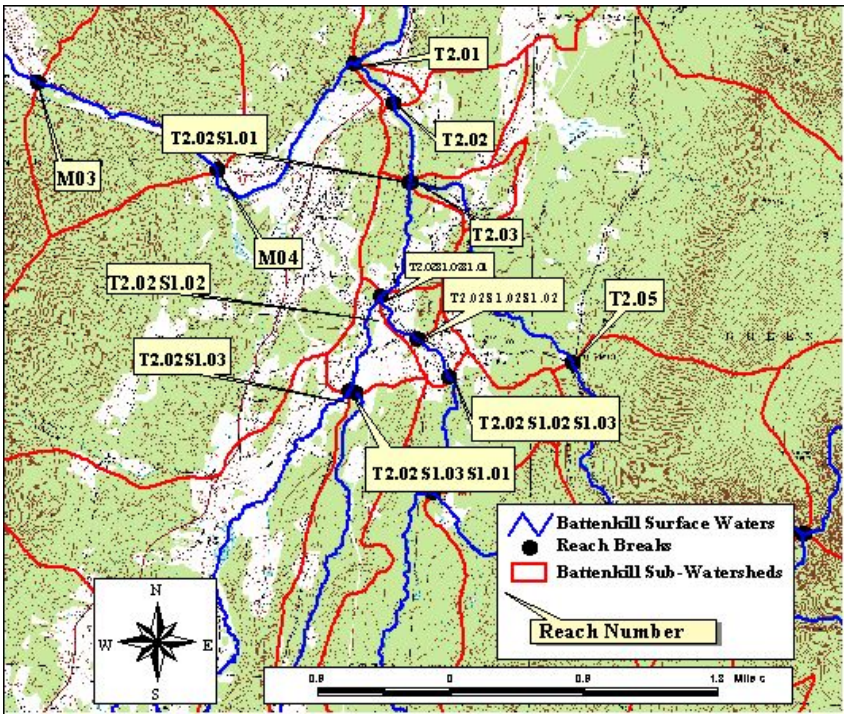


**Figure 1.5** Example of reach numbering system. All reaches on tributary T1 would be preceded by M01, for example, M01T1.01, M01T1.02, etc.; for graphical presentation, it has been left off for this example.

**5. Special Circumstances – Where NOT to collect data**

Surface waters that are not functioning as a fluvial system, such as wetlands, ponds, lakes, and impoundments, should not be assessed using this protocol. However, to run the SGAT ArcView tool the surfacewater theme must be contiguous. Therefore if a wetland, pond, lake or other impoundment is located between reaches in the stream system it should be assigned a reach number in SGAT (Figure 1.4). SGAT will automatically collect some data, such as soils and land use, for the waterbody, and this data will be imported into the DMS. You will have an oportunivy in the DMS to "exclude" the reach from further assessment by selecting a checkbox that indicates the section of stream is impounded.

In order to prevent data entry and analysis errors in the DMS, the user can use the "exclude" button to eliminate from the dataset those reaches for which data was collected in SGAT but the complete set of Phase 1 data was not completed. **Refer to the DMS directions in Appendix B for further detail on excluding reaches.**

**6. Watershed Orientation**

While you may be familiar with your watershed, before beginning an assessment you may not have viewed the watershed in the context of a watershed assessment. Getting out to see the watershed and its streams by car or boat at the start of an assessment can facilitate the assessment process by answering many questions that will arise later during the assessment.

The Watershed Orientation is useful in refining and verifying the "first-cut" reach breaks. Specifically, it allows for a more detailed mapping of valley walls and field verification of valley confinement. It also provides an on-the-ground look at parameters that you will later assess from maps and orthophotos, allowing you to calibrate your eye as to how features you see on the ground appear on the maps and orthophotos. The types of information that may be collected during the orientation are listed in the table below. The Phase 1 protocol step number is listed next to each parameter and the "Notes" column suggests what to look for during the orientation.

***First, read the Phase 1 protocols***. Before starting the watershed orientation, overview the protocols, paying particular attention to the parameters listed in the table below so you know which features are important to note during the watershed orientation. For example, reading Steps 1 and 2 and Appendices D and E will help you successfully identify valley wall features on the topographic map.

The Watershed Orientation is not intended to be an exhaustive survey of the entire watershed that captures all notable features in the watershed. Spend as much time as you can, but do not expend so much time that it keeps you from completing the rest of the assessment. For example, it is not expected that you will see every mile of stream in your watershed and record all grade controls present. The Windshield Survey in Phase 1 Step 7 and Phase 2 assessments are designed to confirm Phase 1 observations and help fill in the data gaps over time.

**Table 1.2** Parameters and map codes for use in watershed orientation surveys.

| Step Number | Parameter | Map Code | Notes |
|---|---|---|---|
| **2.10 and "First-cut reach breaks"** | Valley Type and Confinement | Record valley toe locations on map, and generally note valley widths relative to channel widths. **Verify visual first-cut reach breaks.** | |
| **3.1** | Alluvial Fan | **AF** | Map locations of any observed alluvial fans. |
| **3.2** | Grade Controls | **GC** | Map locations and types of any grade controls observed. |
| **4.2** | Corridor Land Use / Land Cover | Become familiar with how land use/cover types appear on maps and orthophotos. | |
| **4.3** | Riparian Buffer | Become familiar with how riparian vegetation appears on orthophotos. Generally note riparian buffer widths and vegetation types. | |
| **4.4** | Groundwater Inputs | **Trib SS** | Map locations of any observed small tributaries and groundwater inputs (wetlands, seeps, springs) not already visible on maps |
| **5.1** | Flow Regulation / Water Withdrawal<br>Snowmaking withdrawal<br>Irrigation withdrawal | **Dam Weir Snow Irrig** | Map locations of any observed flow regulation and water withdrawal structures |
| **5.3 and 5.4** | Channel and Bank Modifications<br>Rip-rap<br>Tree Revetments | **rprp trvt** | Become familiar with how channel modifications and bank revetments appear on orthophotos. |
| **6.1 and 6.2** | Corridor Encroachments<br>Berms<br>Roads<br>Development-Resid./Comm. | **B RD D-R/C** | Become familiar with how corridor encroachments appear on maps and orthophotos. Map locations of observed features that are not viewable on maps and photos. |
| **6.3** | Sediment storage<br>Mid-channel bar<br>Point bar<br>Delta bar | **Mbr Pbr Dtbr** | Become familiar with how sediment deposits appear on orthophotos. Map locations and types of any observed sediment deposits not viewable on orthophotos. |

***Make good field maps***. Take field copies of your topographic maps and orthophotos with you on the orientation surveys to record the watershed features and characteristics you observe. . You can use the maps to record new features that are not visible on the maps/photos and to verify those features that are visible on the maps/photos. Reference the field maps when completing the rest of the assessment. Standard map codes for field mapping are provided in Table 1.2. See Appendix A for additional map codes and symbols.

***Using a GPS:*** You may choose to use a handheld GPS (Global Positioning System) unit to document feature locations that can later be imported into GIS software as a data layer. This is particularly useful in recording grade control and valley wall toe locations that are not apparent on the topographic maps, but are obvious in the field. You can then use these GPS points later to create digital data layers of grade controls and valley walls, the latter of which can be used in the SGAT program. Depending on how you plan to use the data, you may or may not need the greater level of accuracy that GPS can provide. Using a GPS unit is not required for the Phase 1 assessment and should only be considered when project goals demand a high level of accuracy for location data, as data collection and management can be time consuming. See http://www.dnr.state.wi.us/maps/gis/documents/gps_tools.pdf for information on how to use GPS.

***Take good pictures*** to document unique features (such as grade controls) and general watershed characteristics (such as channel size and valley form) throughout the watershed. Be sure to record the number of the picture and the location that it was taken using the standard photo log form (Appendix A). If you change roles of film mark the roll with tape as to which area/locations the roll represents, and be sure to transfer this information to the envelope in which you submit your film for processing. Reference these pictures when completing the rest of the assessment.

# Step 1. Reach Location

## Overview

Once the geomorphic reaches have been delineated and numbered, as described in the previous section, you are ready to begin the first step in the Phase 1 assessment process, which is to formally locate your reaches. Locating the reaches involves writing a location description, identifying the Vermont municipality in which the reach is located, and providing a latitude and longitude for the upstream and downstream ends of the reach.

Reach location information serves the purpose of helping you and others find the reach on the ground during windshield surveys and later phases of Stream Geomorphic Assessment. The process of sorting, mapping, retrieving, and collating Phase 1 data is also facilitated by reach location information.

## Data Sheet 1. Reach Locations

### 1.1 REACH DESCRIPTION

**Evaluation**
The reach description should help someone unfamiliar with the area to locate the reach. Try to provide as much detail to your description as you can; for example, give a distance and compass heading from a named landmark, road crossing, or road mile marker to the upstream end of the reach. All reaches should be marked on a topographic map and labeled with reach numbers.

**Example:** Reach M01: Off Rt. 100, 2 miles up from Rt.100 / Bridge St. intersection in Granville. Reach begins NE approximately 1/2 mile off Rt.100 just above tributary entering on the east bank.

### 1.2 TOWN (SGAT)

**Evaluation**
Version 4.56 of SGAT will automatically determine the town(s) where the reach is located. If a reach is located in more than one town**,** th**e**n SGAT lists all towns in which the physical stream, not the subwatershed, is located. When the SGAT data is uploaded to the DMS the **town (s)** will automatically be imported for each reach.

### 1.3 LATITUDE / LONGITUDE & NAD 83 State Plane Coordinates (SGAT)

**Evaluation**
Latitude and longitude are north/south and east/west values, respectively, recorded as degrees, minutes, and seconds. Record the latitude and longitude values for the upstream end of the reach and the downstream end of each reach. Computer mapping tools such as GIS, Maptech Terrain Navigator®, and Delorme Topo USA® provide latitude and longitude as degrees/minutes/seconds. For example: Longitude $44^{o}$ 17' 00''N and Latitude $73^{o}$ 17' 30''W. If you plan to access the data in the future using ArcView or other GIS mapping software, it is important to use 1983 datum and to use decimal degrees. It is possible to convert degrees/minutes/seconds into decimal degrees by dividing the minutes and the seconds each by 60 and then adding these to the degrees: [degrees + (minutes/60) + (seconds/60)]. GIS data sets from VCGI and the ANR are generally in NAD 83 State Plane Coordinates (in meters). **SGAT will automatically generate the latitude and longitude and the NAD 83 State Plane Coordinates for each reach break.** When the SGAT data is uploaded to the DMS the latitude/longitude and NAD 83 state plane coordinates will automatically be imported for each reach.

## Step 2. Reference Stream Types

### Overview

**Background:**
Reference stream types are designated to describe stream channel forms and processes that would exist in the absence of human-related changes to the channel, floodplain, and/or watershed. Given the long history of stream channelization and human-related changes to the Vermont landscape, reference stream types are based largely on characteristics of the valley, geology, and climate of the reach.;

**Evaluation:**
In Step 2 you will measure stream characteristics, including valley slope and confinement, to start the process of designating a reference stream type to each geomorphic reach in the watershed. Only those stream characteristics that can be efficiently measured using maps and other remote sensing tools are evaluated in Step 2 of the Phase 1 protocols. The refinement of reference reach characteristics will continue through the entire Phase 1, 2, and 3 protocols. Verification and refinement of reference stream types is done by observing sediment and hydrologic characteristics, as well as channel, floodplain, and terrace land forms. At the end of Phase 1 Step 2 you will have a **preliminary** reference stream type designated for each reach in the watershed.

At this phase of assessment do not expect your measurements to reflect on-the-ground conditions exactly. These measurements are broad characterizations for a large area of land.

**Evaluation with SGAT:**

**You MUST use the SGAT GIS extension to complete the assessment.**

The term "SGAT" appears in parentheses after each parameter for which SGAT can be used to generate data. SGAT will generate data for the following Step 2 parameters:

2.2 valley length
2.4 channel length
2.8 valley width

Valley width and length values are only generated in SGAT for those reaches where you choose to delineate valley walls by creating a GIS polygon theme (usually done along most mainstem rivers, larger tributaries, and in some cases smaller tributaries in wider valleys). **The user MUST enter valley lengths for all reaches where the valley walls were not drawn. This data can be entered directly into the DMS or the SGAT Step 10 dialog. For those reaches which do not have valley walls in the user-supplied valley wall theme, the user has two options for determining the confinement ratio**:

1) If you can accurately estimate the valley width you should measure it and enter the values into either the Step 10 SGAT dialog or directly into the DMS. When the SGAT data is uploaded to the DMS the values will automatically be imported for each reach and the DMS will calculate the confinement ratio for you.
2) If you cannot accurately estimate the valley width than you **should not** enter any values in the Step 10 SGAT dialog box. Once the SGAT data is imported into the DMS you will have an opportunity to manually estimate the confinement for the reach.

Read the discussion under Valley Width (2.9) and Appendix E for further definition and explanation of delineating valley walls. Refer to the SGAT User's Manual for information on how to create a valley wall GIS polygon theme.

## Data Sheet 2. Stream And Valley Type

### 2.1 DOWNSTREAM AND UPSTREAM ELEVATIONS (SGAT)

**Meta Data:**
- USGS 1:24,000 topographic maps
- 1:5,000 DEM
- 1:24,000 DEM

**Evaluation:**
Using one of the data sources listed above, record the elevation of the **downstream** end of each reach into the SGAT Step 10 data entry dialog box. The DMS uses the elevations for successive reach breaks to determine the change in elevation between reach breaks in calculating valley and channel slopes.

*When reading elevations from computer mapping programs it is important to verify the elevations given by the program with those interpreted from an original USGS topographic map.* Not all computer programs use corrected digital elevation models (DEMs) for their base map and this can lead to incorrect elevations. *Do not assume that the elevation given by the computer is correct.* Also, be sure that elevations on all of the topographic maps you are using are in feet (NOT METERS), as slope measurements will be incorrect if elevation units are not in feet.

Record the elevation of the contour line crossing the stream nearest the reach endpoints. If contour lines are far apart and a reach endpoint lies between, interpolate the elevation based on the distance between the contour lines. For example, a reach endpoint located halfway between the 720' and 740' contour lines would be recorded as 730'.

For reaches in gentle gradient valleys (typically < 2%), it may not be possible to discern between downstream and upstream elevations. Where this is the case, do not guess. Do not record elevations for these reaches, and check the "Gentle Gradient" check box on the datasheet and in the DMS. Phase 3 field surveys involving an established elevation benchmark are required to accurately set upstream and downstream elevations for these gentle gradient stream reaches. If the elevations are determined with a survey during a Phase 3 assessment change the meta-data in the DMS.

**Data Entry:**
If the downstream elevations are entered in the Step 10 dialog for each reach in SGAT then when the SGAT data is uploaded to the DMS the elevations will automatically be imported for each reach. Otherwise you have an opportunity to enter both the upstream and downstream elevations for each reach directly into the DMS.

### 2.2 VALLEY LENGTH (SGAT)

**Meta Data:**
- SGAT automated
- 1:24K topos
- 1:24K topos & 1:5K orthos

**Background:**

The valley length represents the straight-line distance parallel to the valley walls between the reach end-points (see Figure 2.1). Do not follow the meanders of the stream. Be sure not to "leap over" any hill-sides when measuring the valley length.

**Evaluation:**
Valley length values are only generated in SGAT for those reaches where you choose to delineate valley walls by creating a GIS polygon theme (usually done along most mainstem rivers, larger tributaries, and in some cases smaller tributaries in wider valleys). **For those reaches which do not have valley walls in the user-supplied theme, the user must manually measure the valley length** and enter the values in the Step 10 SGAT dialog box.

**Data Entry:**
When the SGAT data is uploaded to the DMS the values for valley length will automatically be imported for each reach. **If you do not enter a valley length in SGAT, you must enter them in the DMS, or the DMS will not be able to calculate the valley slope and you will not have the data necessary to determine the reference stream type.** Use the meta data in the DMS to indicate whether the valley length has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

Read section 2.4 (channel length) to understand the difference between valley length and channel length. The length of the valley (in feet) is the straight-line distance parallel to the valley walls between the reach endpoints (see Figure 2.1).

If you are using paper maps, use the scale at the bottom of the map to determine the valley length, or read the length directly from your map wheel if it has the same scale as your map. If necessary, lengths measured in miles can be converted to feet by multiplying miles by 5,280 (1 mile = 5,280 feet). If you are using computer mapping software to measure valley length and subsequent parameters, utilize the software's measuring tool and otherwise follow the same procedure for using a map wheel on a paper topographic map.

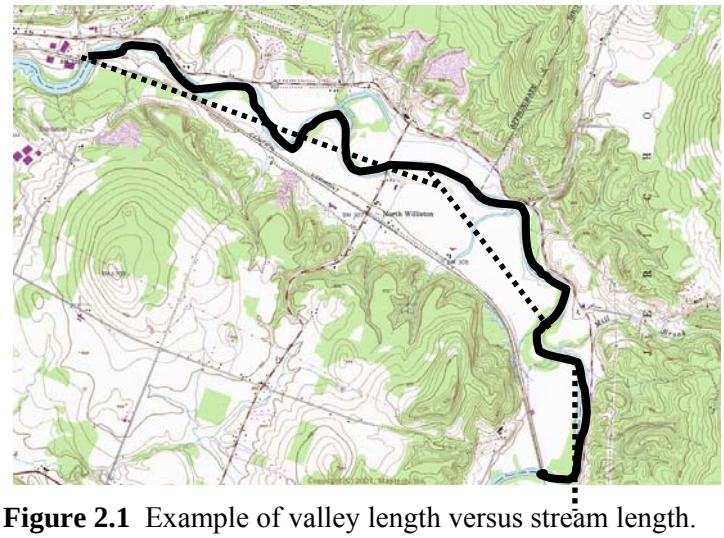

**Figure 2.1** Example of valley length versus stream length.

## 2.3 VALLEY SLOPE (SGAT)

**Data Sources:**

- Step 2.1 and Step 2.2

**Evaluation:**

The DMS will automatically calculate the valley slope for each reach that has values for upstream and downstream elevations as well as the valley length. The DMS uses the reach endpoint elevations recorded in the SGAT Step 10 dialog box to subtract the reach's downstream elevation from its upstream elevation to get the change in elevation for the reach. Next the DMS will divide the change in elevation by the reach valley length determined in SGAT to calculate the reach valley slope. The valley slope is multiplied by 100 to get percent slope.

**Example – Calculating Valley Slope**

**1140 ft upstream elevation**
**- 1000 ft. downstream elevation**
**140 ft change in elevation**

$$\frac{\text{difference in elevation (ft.)}}{\text{length of valley (ft.)}} = \frac{140}{4{,}000} = 0.035 \times 100 = 3.5\ \%\ \text{valley slope}$$

**Data Entry:**

If you did not enter upstream and downstream elevations in Step 2.1 due to an indiscernible change in elevation along the reach, use the "Gentle Gradient" check box on the data sheet (and in the DMS) to indicate valley slope.

## 2.4 CHANNEL LENGTH (SGAT)

**Meta Data:**

- SGAT automated
- Field - tape measure
- Field – GPS
- Field - survey

**Evaluation:**

SGAT will generate the channel length based on the 1:5000 VHD surface water theme that is registered in SGAT. Read section 2.2 (valley length) to understand the difference between measuring valley length and channel length.

**Data Entry:**

When the SGAT data is uploaded to the DMS the values for channel length will automatically be imported for each reach. Use the meta data in the DMS to indicate whether the channel length has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

## 2.5 CHANNEL SLOPE (SGAT)

**Data Sources:**

- Step 2.1 and Step 2.4

**Evaluation:**
The DMS will automatically calculate the channel slope for each reach that contains data for upstream and downstream elevations as well as the channel length. The DMS uses the reach endpoint elevations recorded in SGAT Step 10 to subtract the reach's downstream elevation from its upstream elevation to get the change in elevation for the reach. Next the DMS will divide the change in elevation by the reach channel length recorded in Step 2.4 to calculate the channel slope. The channel slope is multiplied by 100 to get percent slope. See example below.

**Example – Calculating Channel Slope**

**1140 ft upstream elevation**
**- 1000 ft. downstream elevation**
**140 ft change in elevation**

$$\frac{\text{difference in elevation (ft.)}}{\text{length of channel (ft.)}} = \frac{140}{6{,}000} = 0.023 \times 100 = 2.3\ \%$$ **channel slope**

**Data Entry:**
None, this is a calculation automated by the DMS.

## 2.6 SINUOSITY (SGAT)

**Data Sources:**

- Step 2.2 and 2.4 results

**Evaluation:**
Sinuosity is the ratio of channel length to valley length. The DMS will calculate sinuosity for those reaches where SGAT was used to measure the channel length and either the SGAT generated valley length or the valley length entered by the user into the SGAT Step 10 dialog.

In general, the narrower the valley, the closer the stream length is to the valley length, with both becoming nearly equal in length in narrowly confined valleys, resulting in a sinuosity close to 1. If the DMS generates sinuosity values less than 1 there is an error in how the valley length measurement was generated in the program. Measure the valley length on-screen to determine if a different value should be entered into the SGAT Step 10 dialog for valley length.

**Example – Calculating Sinuosity**

$$\frac{\text{channel length (ft.)}}{\text{valley length (ft.)}} = 6000 / 4000 = 1.5 \text{ sinuosity}$$

**Data Entry:**
None, this is a calculation automated by the DMS.

## 2.7 WATERSHED SIZE (SGAT)

**Meta Data:**

- 1:24K DEM
- 1:24K topos, 1:5K NHD
- 1:5K DEM

**Background:**

Watershed size, or drainage area is defined as the area of a river basin, measured in a horizontal plane that is enclosed by a topographic divide such that direct surface runoff from precipitation normally would drain by gravity into the river basin (The National Handbook of Recommended Methods for Water-Data Acquisition, USGS, 1977). Watershed size is used for calculating reference channel width (Step 2.8), which is in turn a factor in calculating confinement (Step 2.9), meander width ratio (Step 6.5), wavelength ratio (Step 6.6), and in delineating river corridors and subsequently evaluating them for soils and land use/land cover and floodplain modification impacts (Steps 4 and 5).

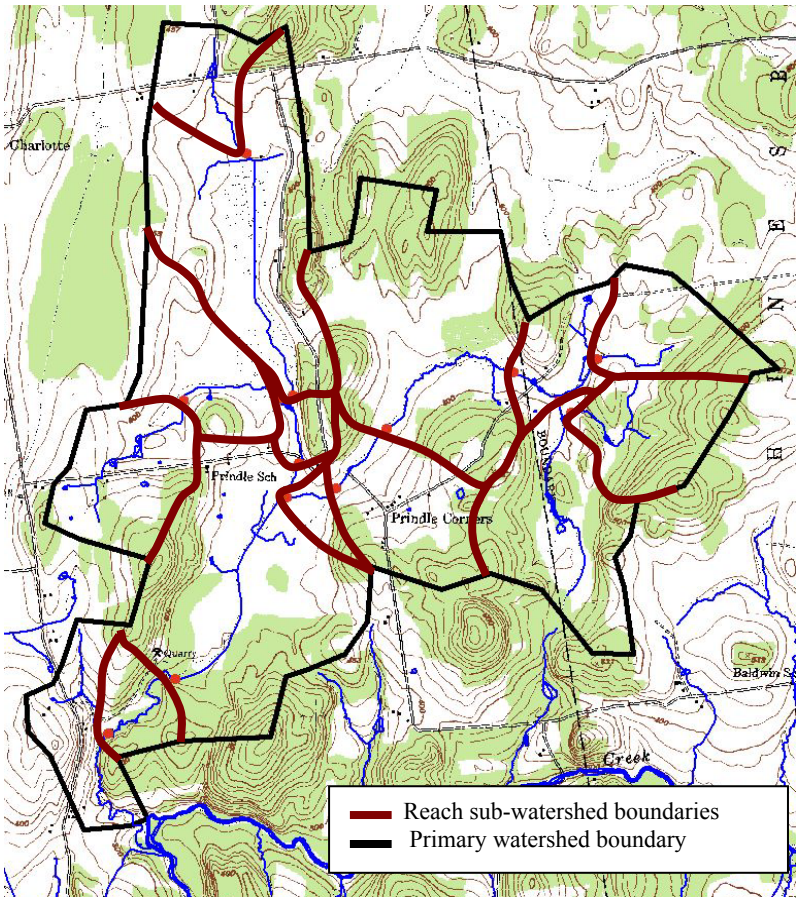


**Figure 2.2** Example of reach sub-watersheds.

**Evaluation:**

SGAT will determine watershed size for each reach, as well as the primary watershed size, from manually digitized reach sub-watershed GIS polygons.

**Data Entry:**

When the SGAT data is uploaded to the DMS the values for watershed size will automatically be imported for each reach.

## 2.8 REFERENCE CHANNEL WIDTH (SGAT)

**Meta Data:**

- HGC - SGAT Automated
- Field - range finder
- Field - tape measure
- Field - survey

**Background:**

Channel width, as referred to in the phase 1 protocols, means the width of the reference condition stream or river at bankfull flows, measured across the channel at the flood height that occurs on an annual to biennial basis. The channel width is generated for all reaches for the purpose of calculating confinement ratios and generating river corridors.

**Evaluation:**
At the Phase 1 stage of assessment you will have to rely on existing field data or a prediction of bankfull channel width calculated from the Vermont regional hydraulic geometry curve (HGC). HGCs for bankfull discharge, and channel cross sectional area, width, and depth have been developed by the River Management Program (Appendix J). At this time the curves are recommended for estimating channel width only on streams and rivers that are similar to those from which the curves were developed. This would include mid-to-large sized streams in unconfined, moderate-gentle gradient, alluvial settings. You should not rely on the curves to characterize channel dimensions for other types of streams throughout your watershed. The HGC for channel width follows the equation below, where "X" is drainage area in square miles. The DMS automatically calculates the channel width in feet by using the watershed size in square miles (calculated in section 2.7) to the 0.50 power (using the $y^x$ function key on your calculator), then multiply this value by 10.18. Round the calculated value to the nearest foot.

**Example – Calculating Channel Width**

**$W = 13.1(X)^{0.44}$, where X = drainage area in sq. mi.**
**if X = 20 sq. mi. then,**
**$W = 13.10\ (20)^{0.44}$ = 49 feet**

For some stream reaches field data exists from surveys that may have included measurements of bankfull channel width. Check for stream-related studies and other developments that would have involved cross-sectional surveys. You should consider all Phase 1 channel width data to be provisional until you can go into the field and measure reference channel width. After conducting a Phase 2 assessment you can update the Phase 1 value for channel width in the Phase 1 DMS with the measured value for those reaches where you are fairly certain that your Phase 2 data is representative of the reach's **reference** condition. *You should not enter field measured channel width values into the Phase 1 DMS if they are from a segment or reach that is in adjustment, especially those measured on over-widened streams or streams undergoing planform adjustment.*

**Data Entry:**
None, this is a calculation automated by the DMS. Use the meta data in the DMS to indicate whether the channel width has been confirmed or changed based on Phase 2 or 3 assessments.

## 2.9 VALLEY WIDTH (SGAT)

**Meta Data:**
- SGAT automated
- 1:24K topos
- Field - range finder
- Field - tape measure

**Background:**
For purposes of Phase 1 assessment the valley may be described as that land area through which the river is free to move laterally over time. A river can be prevented from moving laterally by geologic material of specific quality or quantity. Material such as bedrock, which is resistant to erosion, will limit a river's ability to migrate laterally over time. Erodible material, if in large enough quantities, may also significantly impede the lateral migration of a river over time. For example, a river that migrates into a large hillslope of erodible sand may erode the toe of the hillslope, but as material from the toe is transported downstream it is replaced by sands that slide into the river from above. Therefore, the margins of non-erodible materials and tall hillslopes are considered valley walls.

Valley width is the horizontal distance across the valley floor that is between and perpendicular to the valley side slopes (valley walls). The change from the relatively flat valley bottom to the side slope is marked by significant breaks in slope indicated by the tightening of contour lines as the valley side slopes become steeper. Some low valley terraces, depending on their soil or geologic make-up, may confine or effectively stop the lateral movement of a stream channel. In such instances it is helpful to have knowledge of soils and geologic parent material when determining valley walls, and thus valley widths. Soil and geology maps will provide some insight as to whether a stream has deposited material there before or whether the soils are erodible.

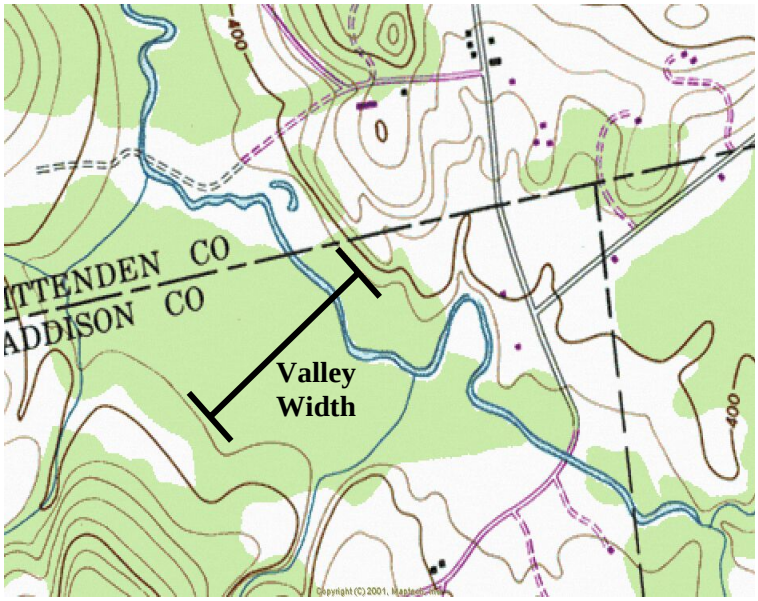


**Figure 2.3** Example of valley width on a topographic map

**Evaluation:**
Valley width values are only generated in SGAT for those reaches where you choose to delineate valley walls by creating a GIS polygon theme (usually done along most mainstem rivers, larger tributaries, and in some cases smaller tributaries in wider valleys). **For those reaches which do not have valley walls in the user-supplied valley wall theme, the user has two options:**

1) If you can accurately estimate the valley width you should enter the values in the Step 10 SGAT dialog box. When the SGAT data is uploaded to the DMS the values will automatically be imported for each reach and the DMS will calculate the confinement ratio for you.
2) If you cannot accurately estimate the valley width than you should NOT enter any values in the Step 10 SGAT dialog box. Once the SGAT data is imported into the DMS you will have an opportunity to manually select the confinement for the reach.

If you elect to manually measure the valley widths they should be measured using the USGS topographic maps (Figure 2.3). Along the reach, measure several widths with a ruler, map wheel, or computer measuring tool and record the average valley width in feet. It may be hard to get a map-based measurement in narrow, V-shaped valleys because there is not enough topographic detail to show the true valley bottom. Use valley slope as a guide. Where it is difficult to get a sense for the width of the valley bottom and the valley slope is greater than 1.5%, label the valley as "confined" (valley types 1-NC or 1-SC, Table 2.1) pending field verification. Often in these cases, valley width is equal to or only slightly greater than channel width, but do not be surprised if this does not always hold true. Valley floors that appear narrow on a 1:24,000 topo map with 20-foot contour intervals may actually contain a floodplain that is broad in comparison to the small stream that is flowing there.

**Data Entry:**
When the SGAT data is uploaded to the DMS the values for valley width will automatically be imported for each reach. Use the meta data in the DMS to indicate whether the valley width has been confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

## 2.10 CONFINEMENT: Ratio of Channel Width to Valley Width (SGAT)

**Meta Data:**
- 1:24K topos
- 1:24K topos, SG data
- Field observation
- Field - tape measure

**Evaluation:**
To calculate the confinement ratio the DMS divides the valley width measured in Step 2.9 by the channel width calculated in Step 2.8. The DMS uses the categories listed in the table below to determine the confinement type. For those reaches that did not have a valley width come out of SGAT, use the table below as well as the guidance under the valley width category to estimate and manually enter the confinement ratio into the DMS.

**Table 2.1 Confinement Ratios**

| Valley Type | Confinement | Ratio = Valley Width/Channel Width |
|---|---|---|
| NC | Narrowly Confined | ≥ 1 and < 2 |
| SC | Semi-confined | ≥2 and <4 |
| NW | Narrow | ≥4 and <6 |
| BD | Broad | ≥6 and <10 |
| VB | Very Broad | ≥10 -with abandoned terraces on one or both sides |

This ratio is only as accurate as the channel and valley widths used in the derivation. You should consider all Phase 1 confinement ratios and valley types to be provisional until you can go in the field, measure the reference condition channel width and the natural valley width. Where channel and valley widths are difficult to determine using remote sensing techniques, it is recommended to at least nominate a valley type for every reach. While there will be exceptions that will have to be corrected later, the analytical power of the Phase 1 DMS will be much greater when provisional valley types have been assigned to each reach.

**Data Entry:**
When the SGAT data is uploaded to the DMS the valley width will automatically be imported for each reach and the DMS will calculate the confinement ratio and determine the appropriate valley type. For those reaches that did not have a valley width come out of SGAT manually enter the estimated confinement type into the DMS.

## 2.11 REFERENCE STREAM TYPE

**Meta Data:**
- 1:24K topos
- Field observation
- Cross-sections, pebble counts
- Profile, cross-sections, pebble counts

**Background:**
Several stream classification systems have been developed to describe the physical characteristics of streams. Two of the most commonly used systems are those of Rosgen (1996) and Montgomery-

> "Delineating stream types provides an initial sorting of types within large basins and allows a general level of interpretation. Field checking the "remote sensing" mapping effort that utilizes aerial photographs and topographic maps can lead to proper interpretations. Delineation of stream types at this broad level leads to data organization and the ability to develop a set of analysis priorities for the next, more detailed level of stream classification inventory." (Rosgen, 1996)

Buffington (1997). Table 2.2 below combines several features of these systems. The reference stream type describes the natural central tendency of channel form and process that would exist in the absence of human-related changes to the channel, floodplain, and/or watershed. Given the long history of stream channelization and of human-related changes to the Vermont landscape, the reference stream type is based largely on characteristics of the valley, geology, and climate of the stream.

The Phase 1 DMS serves as a repository for reference stream type information and other provisional data until Phase 2 and Phase 3 field assessments can be conducted. Remote sensing data in the Phase 1 DMS provide a powerful tool for guiding watershed-level decisions, especially when conducting field assessments on every reach in the watershed is impractical in the near term. As the Phase 1 DMS becomes populated by reference stream type evaluations and impact ratings refined by field data, it will become an even more rigorous guidance tool for watershed planners and managers.

In a Phase 1 assessment, reference stream types are defined for each reach by evaluating reach valley slope and confinement in Step 2 and are further refined using bed form and channel substrate data collected during the windshield survey (Step 7). Assigning a reference stream type using remote sensing and windshield survey data should be considered "provisional." Field assessments (Phase 2 and Phase 3) consider other channel characteristics to assign "existing" stream types, such as the degree to which the channel can access its floodplain. Where field assessments indicate the absence of major human-related stressors and little or no channel adjustment, the field data used to type the reference condition can be used to refine the reference stream type assigned in the Phase 1 assessment (and to update the Phase 1 DMS). The Phase 1 DMS is reserved for reference stream type data in order to maintain a consistent data layer for reaches throughout the watershed (even though some evaluations may be more provisional than others). This reserves the data necessary to contrast reference stream types with the existing stream types determined in Phases 2 and Phase 3.

**Evaluation:**
Using Table 2.2 as well as the more detailed descriptions below to determine the stream type for each reach based on the confinement and valley slope. Record the letter/text description of the stream type on the data sheet. During windshield surveys (Step 7) you may have an opportunity to verify valley confinement, dominant bed materials, and bed forms, and thus further define the reference stream type designation. More detailed information on the variables and descriptors used in field stream typing are provided in Appendix I and described further in the Phase 2 Handbook, Step 2.14 and in the Phase 3 Handbook, Step 6.

**Table 2.2 Phase 1 – Reference Stream Typing Chart**

| Reference Stream Type | Confinement (Valley Type) | Valley Slope |
|---|---|---|
| A | Narrowly confined (NC) | Very Steep > 6.5 % |
| A | Confined (NC) | Very Steep 4.0 - 6.5 % |
| B | Confined or Semi-confined (NC, SC) | Steep 3.0 - 4.0 % |
| B | Confined or Semi-confined or Narrow (NC, SC, NW) | Mod.- Steep 2.0 – 3.0 % |
| C or E | Unconfined (NW, BD, VB) | Mod.- Gentle < 2.0 % |
| D | Unconfined (NW, BD, VB) | Mod.- Gentle < 4.0 % |

* Use the Gentle Gradient descriptor rather than a calculated slope value for those reaches where elevations were not recorded in Step 2.1. In this table the D / Braided channels may have the same valley confinement and slope characteristics as C stream types. Only set the provisional reference stream type as a D / Braided channel after observing a braided channel on the topographic maps, orthophotos, or windshield survey, or based on the presence of an alluvial fan (see Step 3.1). Only choose the E stream type (rather than C) where sinuosity values are greater than 1.5 and where windshield survey observations support this stream type assignment.

**DOMINANT BED FORM / MATERIAL**

**Background:**
The type and distribution (sorting) of material found in the bed of the stream reflects the source and supply of sediments as well as the competency of the channel to transport the sediment (a function of the channel depth and slope). Measurements of the bed material and observation of bed form help characterize the stream's ability to carry different size material.

The Phase 1 windshield survey will give you an opportunity to field verify your selected stream types consistent with the Montgomery-Buffington Stream Classification System (1997). Bed forms are examined in more detail in Phase 2 and Phase 3 field assessments when the entire stream reach is assessed.

Steeper reaches of a watershed generally have cobbles and boulders sorted into step-pool bed forms. This is because the stream easily transports smaller materials downstream and scours larger materials over relatively shorter distances into lines called steps. As you go further down in the watershed, where slopes are more shallow, the bed material generally becomes finer, moving towards sands and gravels near the mouth of most large rivers in Vermont.

**Evaluation:**
Choose the bed form and dominant bed material size class which best describe the reach from the menus below. Indicate "No Info" if you cannot see enough of the reach to make a determination.

**Menu**

| Bed Forms | Description |
|---|---|
| **Cascade** | Generally occur in very steep channels, narrowly confined by valley walls. Characterized by tumbling jet and wake flow, disorganized bed materials (typically bedrock, boulders, and cobbles). Small, partial channel-spanning pools spaced < 1 channel width apart common. |
| **Step-Pool** | Often associated with steep channels in confined valleys. Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. |
| **Plane Bed** | Occur in low to high gradient and relatively straight channels and may be either unconfined or confined by valley walls. Composed of sand to small boulder-sized particles, but dominated by gravel and cobble substrates in reference stream condition. Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed. |
| **Riffle-Pool** | Occur in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys, and have well-established floodplains. Channel has undulating bed that defines a sequence of riffles, runs, pools, and point bars. |

| Bed Forms (cont) | Description (cont.) |
|---|---|
| **Dune-Ripple** | Usually associated with low gradient and highly sinuous channels. Dominated by sand-sized substrates. Channel may exhibit point bars or other bed forms forced by channel geometry. Typically undulating bed does not establish distinct pools and riffles. |
| **Braided** | Multiple channel system found on steep depositional fans and deltas. Channel gradient is generally the same as the valley slope. Ongoing deposition leads to high bank erosion rates. Bed features result from the convergence/divergence process of local bed scour and sediment deposition. Unvegetated islands may shift position frequently during runoff events. High bankfull widths and very low meander (belt) widths. |
| **Bedrock** | Lack a continuous alluvial bed. Some alluvial material may be temporarily stored in scour holes, or behind obstructions. Often confined by valley walls. |
| **Not Evalu-ated** | The reach was not accessed during the windshield survey. |

Be careful, as casual observations of dominant bed material type are often biased toward the larger particles. If you can get down close to the stream, observe the smaller particles that are often entrained around larger substrates, and be sure to consider these in your evaluation of dominant bed material.

**Menu**

| Bed Materials | Millimeters | Inches | Relative Size |
|---|---|---|---|
| **Bedrock** | | | Ledge outcrop |
| **Boulder** | 256 – 4096 | 10.1 – 160 | Basketball to Volkswagen Bug |
| **Cobble** | 64 – 256 | 2.5 – 10.1 | Tennis ball to basketball |
| **Gravel** | 2 – 64 | 0.08 – 2.5 | Pepper corn to tennis ball |
| **Sand** | 0.062 – 2.00 | 0.002 -0.08 | Silt size to pepper corn |
| **Silt** | <.062 | <.002 | Smaller than sand |
| **Not Evaluated** | The reach was not accessed during the windshield survey. | | |

**Sub Class Slope:**
In a Phase 1 assessment, the slope subscript is only used if the confinement and slope do not fit into one stream type category, as listed in Table 2.2. The "primary" stream type always describes the confinement and a subscript is only used if the streams slope is not within the range for the confinement type.

For Example: If a stream is semi-confined with a slope around 1.0% that it would be a stream type $B_c$ based on a confinement of a "B" and the slope of a "C".

**Menu**

| Slope Subscript | Slope % |
|---|---|
| a | >4 |
| b | 2-4 |
| c | <2 |
| None | N/A |

**Data Entry:**
Enter stream type, subclass slope, bed form and dominant bed material size class data into the Phase 1 DMS under Step 2. Use the meta data in the DMS to indicate whether the reference stream type has been

confirmed or changed based on windshield surveys or Phase 2 or 3 assessments.

**Data Entry:**
The Phase 1 DMS contains menus to choose from the full complement of stream type descriptors used in the Rosgen (1996) and Montgomery-Buffington (1997) classification schemes. This way, further details of reference stream characteristics determined later in Phase 2 or Phase 3 field assessments can be incorporated in the Phase 1 watershed-wide DMS. For instance, during a Phase 1 assessment you may provisionally set the reference stream type of a reach as "B / Plane bed." Then in the field, you may determine that the dominant bed material type of the reference condition is cobble-sized. In this case, you would want to revise the reference reach stream type to a "B3 Plane bed."

Use the meta data field in the DMS to indicate whether the reference stream type for the reach was refined or changed based on windshield surveys or Phase 2 or Phase 3 assessments.

**Stream Types and Aquatic Habitat**

As indicated in Table 2.2, stream types are associated with specific bed forms and valley characteristics, which determine, in part, the types of habitat available for stream-dwelling organisms. In general, different species utilize different stream types, as they have adapted to specific physical, chemical, and biological components found in these different stream types. Many species will utilize more than one stream type, but few species are adapted to utilizing all stream types well. Some generalizations can be made about what species you might expect to find in certain stream types. For example, the Northern Spring salamander (*Gyrinophilus porphyriticus*) commonly inhabits very cold, well-oxygenated headwater streams and spring seeps, which are usually associated with A type, and possibly B type, streams. The physical characteristics of A and B stream types that contribute to keeping these streams cold and well-oxygenated are their narrow, steep valleys, which are typically still forested, since these valleys are often unsuitable for other land uses. The narrow valley helps shade the stream, and the forest cover slows run-off, shades the ground surface, and enhances groundwater recharge, all of which contribute to cold water temperatures in the stream. In addition, steep, confined valleys result in stream bed forms that are more turbulent (cascades and steps) which, along with cold water temperatures, result in well-oxygenated water. In contrast, the Northern Spring salamander is not likely to be found in low gradient, large rivers that are typically warmer and support other organisms, such as fish, which compete with and prey on these salamanders. Similarly, a species which is adapted to warm water temperatures and is not a strong swimmer, such as a Pumpkinseed (*Lepomis gibbosus*) will not likely be found in an A or B type streams, which are typically cold water systems with faster flows. The pumpkinseed is common, however, in low gradient, slow moving streams and rivers, which are usually C and E stream types. Due to their broad, low gradient valleys, mix of land cover types, and generally larger watershed sizes, C and E type streams are usually warmer, slower moving, and possibly less well-oxygenated than headwater A type streams and most B type streams.

# Step 3. Basin Characteristics: Geology and Soils

## Overview

**Background:**
The stream types identified in Step 2 provide basic information on how streams function, or work, to transport the water and sediment produced in their watersheds. This is critical to understanding the adjustment processes a stream may go through in response to the channel and floodplain modifications examined in Steps 5 and 6. Sediment supply, as a factor in stream equilibrium, is also related to the geology and soils of a stream's watershed. The geologic materials underlying a watershed have a strong influence on stream processes. These materials include both the solid ledge, or bedrock, and the unconsolidated sediments that overlie the bedrock. A stream carries not only water, but also sediment. Geology determines the source material that the river is carrying, the way that material is carried, and the rate of channel adjustments.

Stream reaches that have beds and banks composed of surficial geologic materials such as gravel, sand, silt, clay, or mixes of these are far more erodible than any of the types of unweathered bedrock found in Vermont. This leads to a fundamental distinction between the bedrock-controlled reaches and those underlain by surficial deposits. Stream reaches that have bedrock-controlled beds and banks are relatively static systems. The planform of a stream flowing over bedrock is largely controlled by preexisting weaknesses such as relatively soft geologic units, bedding and other layering within the rock units, and fractures in the rock such as faults or joints. Thus, a straight reach constrained by bedrock may owe its shape to a fault in the underlying rocks and a sharp bend in the stream may be due to one or more joints in the rock. Such fractures can provide an easy path for the stream to follow because the rock weathers faster along the fractures. Under present stream flow conditions, bedrock-controlled streams in Vermont are essentially fixed in position, even when viewed over time frames of a hundred years or longer.

Reaches underlain by surficial deposits can, in contrast, respond to changing watershed inputs over very short time periods. A single flood may drastically alter such a channel and the stream may be able to respond to the new conditions over a period of months, years, or decades in order to reestablish the dynamic equilibrium described in the Program Introduction.

**Evaluation:**
Step 3 will help you to make the distinction between bedrock and non-bedrock dominated stream systems and to subdivide the non-bedrock systems based on the erodibility of the materials in the bed and banks. You will also note features that control or accentuate certain erosion processes, such as grade controls and the steepness of valley side slopes.

***The River Corridor (Created in SGAT )*:** From Step 3 on you will be evaluating several parameters within the river corridor, which is described in detail in Appendix E. It is highly recommended that you secure the resources and expertise needed to undertake analysis of soils and geologic materials using GIS software, the SGAT extension and digital data layers. The monetary investment is well worth the time saved in reviewing and piecing together soils information from soils surveys and other geologic maps.

SGAT automates delineation of the river corridor and the characterization and summation of soil properties within the river corridor for each reach (see below). SGAT delineates the river corridor based on valley walls, meander centerlines, and standard buffer algorithms built into the software. Appendix E explains the general process that SGAT uses to draw the river corridor and the rationale behind the river corridor delineation process.

# DATA SHEET 3: BASIN CHARACTERISTICS - GEOLOGY AND SOILS

## 3.1 ALLUVIAL FAN - CHANGE IN VALLEY SLOPE (FIT)

**Meta Data:**
1:24K topos
1:24K topos, SG data
1:24K topos, SG data, geologic studies
1:24K topos, field observation

**Background:**
An alluvial fan may form where a steep, confined stream valley becomes abruptly less confined and shallower in slope. When the stream becomes shallower, it loses velocity, which reduces its ability to transport sediment. The sediment drops out of the water, blocking the channel and leading to frequent shifts in channel location. Viewed from above, an alluvial fan often has the shape of a wedge of pie, with the narrow point at the upstream end where the confined valley widens out (see Figure 3.2). In Vermont, these fans can range from a few tens of feet to several hundred feet or more across. Excavations on alluvial fans in Vermont show that although much of the material accumulated in the first few thousand years after the end of glaciation, sediment accumulation increased dramatically on many fans in the 19th century in response to the large-scale land clearing associated with increased settlement throughout Vermont (Bierman et.al., 1997 and Jennings et.al., 2003). Since the reforestation of much of Vermont's landscape in the late 19th century and the 20th century, sediment accumulation on the fans has decreased.

**Evaluation:**
It is difficult to determine from map-work alone if the reach has formed on an alluvial fan. This parameter is meant to assess the **possibility** that the reach is located on an alluvial fan. A "yes" answer to this question indicates that further field work may be required. Figure 3.1 shows a possible alluvial fan. Mark possible alluvial fan locations on the topographic map with the symbol "AF". Be sure to only record an alluvial fan that occurs in the reach you are assessing, and not those in tributaries entering the reach you are assessing. These fans should be recorded for the appropriate reaches in those tributaries.

**Menu**

| | |
|---|---|
| **Yes** | Maps suggest an alluvial fan exists in the reach. |
| **No** | Maps do not suggest an alluvial fan exists in the reach. |
| **No Data** | No data sources are available to determine if an alluvial fan exists. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. |

**Data Entry:**
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of alluvial fans. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where an alluvial fan is indicated. For reaches with "no", "no data" or "none" the data field must be manually entered into the DMS.

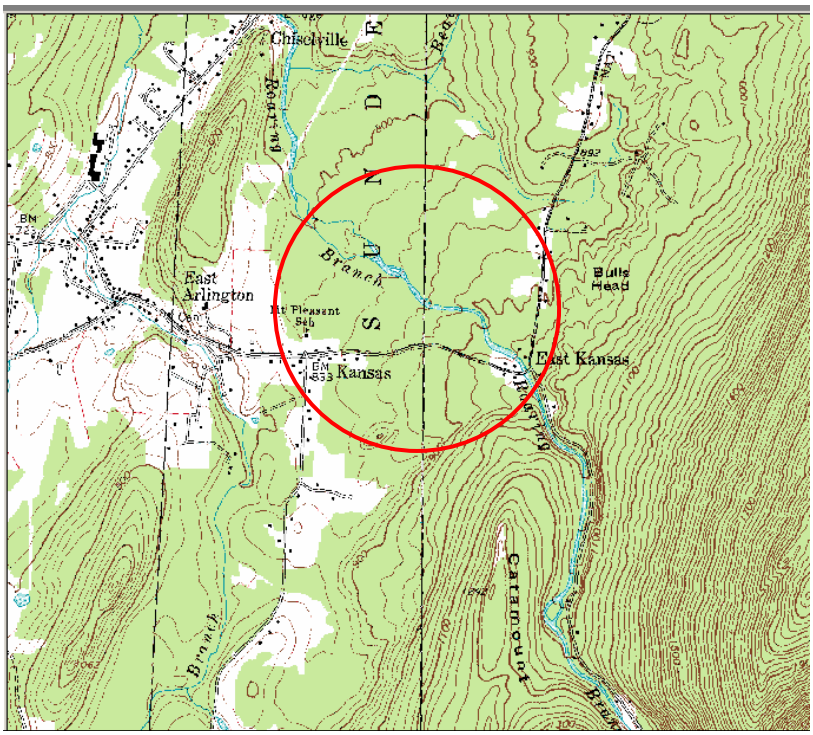


**Figure 3.1** Large alluvial fan indicated by series of parallel, undulating topographic lines.

## 3.2 GRADE CONTROLS (FIT)

**Meta Data:**

- 1:24K topos
- 1:24K topos, bedrock map
- 1:24K topos, bedrock map, dam inventories
- 1:24K topos, field observation.

**Background:**

Grade control, as defined here, is a permanent feature that may impound or slow the water upstream of the feature and limit the ability of a river to cut down into its bed. These physical features provide grade control (Figure 3.3)**.** These features **must** be channel spanning, meaning they go from bank to bank across the channel. Features that provide grade control include:

- dams and weirs;
- bedrock: waterfalls and ledge drops that span the width of the river channel

Grade control is important because it keeps the base elevation of a river from being lowered. When the base elevation is lowered several adjustments typically occur:

- bed forms such as steps and riffles are eroded and floodplain access may be lost;
- vertical channel adjustments propagate upstream, causing channel incision and bank erosion;
- the channel widens during floods introducing sediment into the river system from bank erosion;
- the water table may lower, affecting channel flows, riparian vegetation, and domestic wells; and
- human investments, particularly roads and bridges, can be undermined.

Some grade controls may serve as barriers to movement and migration of aquatic biota. Dams, weirs, and falls, may prevent the upstream and, in the case of some dams, downstream movement of stream-dwelling organisms, particularly fish. Phase 1 results for grade controls can be used to guide further assessments of aquatic habitat connectivity in Phase 2. Bridge and culvert assessments are also important components of assessing aquatic habitat connectivity (see Appendix G: ANR Bridge and Culvert Assessment protocols). Vermont Fish and Wildlife Department fisheries biologists can provide information about known fish migration barriers and can help evaluate suspected barriers.

**Evaluation:**
Indicate known dams, weirs, waterfalls, or bedrock ledges that completely cross the channel. Mark these on the topo map with the letters "GC." Most grade controls are identified in the field, so make sure to note them during the watershed orientation (Step 1) and during the windshield survey (Step 7).

**Menu**

| | |
|---|---|
| **Dam** | Constructed dam or weir |
| **Ledge** | Bedrock ledge |
| **Waterfall** | Bedrock that extends across the channel and forms a vertical, or near vertical, drop in the channel bed |
| **Weir** | At-grade or low cross-channel structures |
| **No Data** | No data sources are available to determine if grade controls exist. |
| **None** | The parameter was researched and no evidence of grade controls can be found. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. |

**Data Entry:**
Use the Feature Indexing Tool (FIT) in SGAT to note the locations of grade controls. When the FIT data is uploaded into the DMS the data will be automatically populated for each reaches where a grade control is indicated. For reaches with "none", "no data" or "not evaluated" the data field must be manually entered into the DMS.

**Figure 3.2** Natural, ledge grade control (left) and dam grade control (right).

## 3.3 GEOLOGIC MATERIALS (SGAT)

**Meta Data:**

- NRCS digital soil survey

**Background:**

Stream equilibrium is, in large part, a function of the size and quantity of sediment which is transported by the stream (i.e., stream type is dictated by sediment regime). Insights to stream type and sediment regime may be made by evaluating the surficial geologic materials available for transport in the watershed and river corridor. The Soil Surveys of the NRCS contain a wealth of information, including interpretations of the surficial geologic materials. Every soil series (the basic soil subdivision) has been assigned a parent material classification. The parent material is defined by NRCS as "...the unconsolidated material, mineral or organic, from which the soil develops" (Natural Resources Conservation Service, 1999, Part 618.40). Geologic materials can also be determined from the surface geologic maps produced by the Vermont Geological Survey, though these maps are at a fairly coarse scale. Descriptions of geologic materials and sources of geologic information are provided in Appendix F.

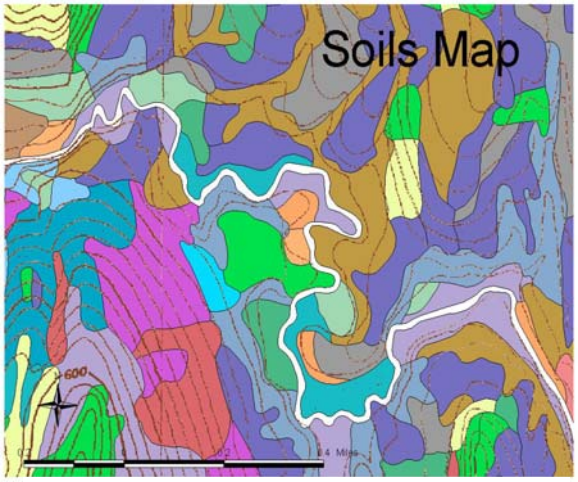


**Figure 3.3** Example of NRCS soil survey

**Evaluation:**

This step is automated with the use of SGAT. SGAT delineates the river corridor as a polygon and then uses the corridor polygon to clip soils information from the NRCS soils maps. SGAT automatically excludes any surface water in the NRCS theme in the analysis. From this SGAT generates a table named "S14SC12." **When the SGAT data is uploaded to the DMS the Soil Properties will automatically be imported for each reach.**

**Menu**

| **Material** | **Description** | **Soils**<br>**Top 20 Table* Codes** | **Erodibility** |
|---|---|---|---|
| **Alluvium** | Alluvial – river sediments | A = alluvial | High |
| **Ice-Contact** | Glacio-fluvial – glacial river deposits | GF = outwash | High |
| **Glacial Lake** | Glacio-lacustrine – glacial lake deposits | GL = lacustrine | Moderate – High |
| **Glacial Sea** | Glacio-marine – glacial sea | | Moderate – High |
| **Till** | Till – glacially deposited sediments | DT = dense till<br>GT = glacial till | Moderate – High |
| **Colluvium** | Rock fall and landslide deposits | NA | Variable |
| **Bedrock** | Bedrock | NA | Low |
| **Other** | | M = miscellaneous<br>O = organic deposits | |

**Data Entry:**

When the SGAT data is uploaded to the DMS the percentage of each geologic material will automatically be determined for each reach.

## 3.4 VALLEY SIDE SLOPES

**Meta Data:**
- 1:24K topos
- 1:24K topos, soils slope data
- 1:24K topos, field observation.

**Background:**
Identifying the presence of steep adjacent side slopes in combination with data on the erodibility of the soils and geologic materials in the river corridor will enable you to query the Phase 1 database for information on erosion potential, watershed sediment supply, and potential mass failure sites.

**Menu:**

| Classification | Percent Slope |
|---|---|
| **Flat** | 0-3% |
| **Hilly** | 4-8% |
| **Steep** | 9-15% |
| **Very Steep** | 16-25% |
| **Extremely Steep** | >25% |

**Evaluation:**
Using topographic maps, describe the typical valley side slopes on the right and left sides of the valley, as viewed looking downstream, using the categories provided in the menu table. Valley slopes can be measured off of USGS topographic maps in the same way as described for calculating valley and channel slopes in steps 2.3 and 2.5.
Use the Windshield Survey (Step 7) to verify valley side slope data.

The NRCS soil surveys (Figure 3.4) are also useful for estimating valley side slopes. The last letter in the three-letter abbreviation for soil types indicates the slope of the land. For example, on a soil survey map a soil polygon may be labeled "BeC," which is a Berkshire (Be) soil with a C slope. The breaks between the various NRCS slope classes vary between soil series. Thus, in one soils series an "A" may range from 0 to 2%, while in another an "A" slope may range from 0-3%. There are guides in each NRCS soil survey explaining different soils and their properties.

With a GIS program digital topographic maps can be overlain, using the DRG Tools extension, onto the digital soils layer. Since each soil type has a slope range, using the soil slope values in conjunction with the topographic lines will result in a more accurate evaluation of valley side slope.
Link the attribute table of the soils layer with the NRCS Top20 table to determine the slope range of each soil type.

**Data Entry:**
Manually enter the data for valley side slope for the right and left valley into the DMS for each reach.
**Note: The right and left bank are determined facing downstream.**

## 3.5 SOIL PROPERTIES (SGAT)

**Meta Data:**
- NRCS digital soil survey

**Background:**
Similar to geologic materials, soils information contributes to the understanding of sediment regime and may be particularly useful in explaining the channel condition (stream type and departure) and the adjustment processes occurring in a reach. In addition, knowing the types of soil and their properties within the river corridor may be valuable in an assessment of water quality, where soils are subject to erosion during stages of channel evolution.

There are several categories of information contained in the NRCS soil surveys that are particularly useful in watershed analysis. These include detailed information on engineering properties of the different soil types, such as permeability, grain size, hydrologic group, depth to bedrock, and depth to seasonal high water table. Soils information can help to characterize the erodibility of the soils, the ability of water to infiltrate into the soils, and the ways in which the soils were created.

**Evaluation:**
SGAT delineates the river corridor as a polygon and then uses the corridor polygon to clip soils data from the digital NRCS soils surveys. SGAT generates a table named "S14SC12," which sums the soil types and dominant soil property characteristics (for the four soil properties discussed above) within the river corridor for each reach. **When the SGAT data is uploaded to the DMS the Soil Properties will automatically be imported for each reach.**

**Data Entry:**
When the SGAT data is uploaded to the DMS the percentage of each of the soil properties will automatically be determined for each reach.

***Hydrologic Group:*** Hydrologic groups for soil types are listed in the NRCS Top 20 table and are grouped according to their runoff characteristics. Some soils are assigned to two hydrologic groups. Dual grouping is used for one of two reasons: (1) Some soils have a seasonal high water table but can be drained. In this instance the first letter applies to the drained condition of the soil and the second letter to the undrained condition. (2) In some soils that are less than 20 inches deep to bedrock, the first letter applies to areas where the bedrock is cracked and pervious and the second letter to areas where the bedrock is impervious or where exposed bedrock makes up more than 25 percent of the surface of the soil.

The chief consideration is the inherent capacity of soil, when bare of vegetation, to permit infiltration. Soils are assigned to four groups. Group A consists of soils that have a high infiltration rate when thoroughly wet and a low runoff potential. They are mainly deep, well drained, and sandy or gravelly. Group D, at the other extreme, consists of soils that have a very slow infiltration rate and thus, high runoff potential. They have a claypan or clay layer at or near the surface, have a permanent high water table, or are shallow over impervious bedrock or other hard material.

**Menu**

| Hydrologic Group | Description |
|---|---|
| **A** | High infiltration rate – low runoff potential. |
| **A/D*** | Seasonally variable: high infiltration rate with low runoff potential **OR** undrained, slow infiltration rate with high runoff potential. |
| **B** | Medium/High infiltration rate |
| **B/D*** | Seasonally variable: Medium/High infiltration rate - low runoff potential **OR** undrained, slow infiltration rate with high runoff potential. |
| **C** | Medium/Slow infiltration rate. |
| **C/D*** | Seasonally variable: Medium/slow infiltration rate- low runoff potential **OR** undrained, slow infiltration rate with high runoff potential. |
| **D** | Slow infiltration rate – high runoff potential. |
| **Not Rated** | Not rated or no hydrologic group assigned. |
| **No Data** | Soils data is not available for the study area. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. |

***Flooding:*** Flooding characteristics for soil types are listed in the Top 20 table under the "frequency of flooding" category. Soils formed in floodplains are indicative of areas where historical channel migration has occurred. Silts and sands are carried by floodwaters and deposited in the floodplain. Over time these floodplain soils can build into deep, rich deposits. The presence of floodplain soils can be used to determine historic channel migration areas. This information is listed under the description of each soil.

**Menu**

| Flooding | Description |
|---|---|
| **None or Rare** | Soil texture not indicative of frequent flooding. |
| **Occasional** | Soil texture indicative of occasional flooding. |
| **Frequent** | Soil texture indicative of frequent flooding. |
| **Not Rated** | Frequency of flooding not indicated for soil type. |
| **No Data** | Soils data is not available for the study area. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. |

***HEL Class :*** Determine the erodibility of soils and estimate the percentage of the reach that contains soil materials that are highly or potentially highly erodible. One option for evaluating this parameter is to read the general description of each soil and use the erosion potential of the soil with no vegetation as the erodibility value assigned to the soil. The overall percentage of highly and/or potentially highly erodible soil values for the reach can be used to choose an appropriate value from the menu below. For example, if the value for highly erodible is 20% and the value for potentially highly erodible is 35%, the overall percentage is 55% and the reach would be considered in the "severe" category for erodibility.

Highly Erodible Land (HEL) is soil erodibility factor which represents both susceptibility of soil to erosion and the rate of runoff, as determined by the USDA Natural Resource Conservation Service (NRCS). The NRCS uses a number of equations, including the Universal Soil Loss Equation (USLE) to determine, for each map unit, a relative index of susceptibility of bare, cultivated soil to particle detachment and transport by rainfall.

This value is for the erosion caused by overland flow on unvegetated soils and does not directly indicate the erodibility of the soils as it relates to the power of the stream working on them. So be aware that a soil type that is listed as being "not highly erodible" may still erode when a stream is working against it. Contact NRCS soil scientists for more information about soil erodibility

**Menu**

| Erodibility | Percentage of reach which contains soils with HELCLASS highly erodible and/or potentially highly erodible |
|---|---|
| **Slight** | 0 – 25 % |
| **Moderate** | 26 – 50 % |
| **Severe** | 51 – 75 % |
| **Very Severe** | 76 – 100 % |
| **No Data** | Soils data is not available for the study area. |
| **Not Evaluated** | All data sources (as described by the meta data) HAVE NOT been evaluated. |

***Water Table*:** Water Table information is usually listed in the Top 20 table or the Water Features table of NRCS soil surveys. Enter the values under both the "watershall" and "waterdeep" categories. Choices are in feet below ground surface, ranging from 0 to >6 feet. This information can be used to determine groundwater inputs to the stream.

***Hydric:*** A hydric soil is a soil that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part. The concept of hydric soils includes soils developed under sufficiently wet conditions to support the growth and regeneration of hydrophytic vegetation. The presence of a hydric soils may indicates that wetlands are present. Vegetation and hydrology must also be considered when making a wetland determination.

| Hydric | Description |
|---|---|
| **Yes** | At least one of the major components in the map unit is hydric |
| **No** | None of the major components in the map unit is a hydric soil. |
| **Unknown** | Unknown if the major components of the map unit is hydric. |
| **Not Rated** | Hydric classification was not noted for the map unit. |

**Geology and Aquatic Habitat**

The geological setting in which a stream is located influences a stream's valley form and bed and bank substrate size and erodibility. These geological influences affect channel form and sediment transport processes, which in turn determine, in part, instream habitat suitability for stream-dwelling organisms. Instream physical habitat is evaluated in detail in Phase 2.

In addition to these physical effects, geology also largely determines a stream's water chemistry, another critical component of aquatic habitat. The weathering of rocks results in various carbonate compounds dissolved in surface waters. These compounds determine a stream's buffering capacity and pH levels, the latter of which can directly influence an organism's health. In general, highly calcareous rocks (those that contain a lot of calcium carbonate, such as limestone) foster streams with high buffering capacity that can maintain a fairly stable pH level within a range that supports aquatic biota. Most igneous rocks, such as granite, do not contain abundant carbonate minerals, and typically result in streams with low buffering capacity. These streams have greater susceptibility to pH swings and low pH levels that can be detrimental to aquatic biota. Figure 3.5 shows a general distribution of calcareous and non-calcareous bedrock types in Vermont. Various studies have also shown that streams rich in cations (especially calcium and magnesium, which are often associated with bicarbonate) are more productive biologically (Allan: 1995), supporting more abundant, and often more diverse, aquatic communities.

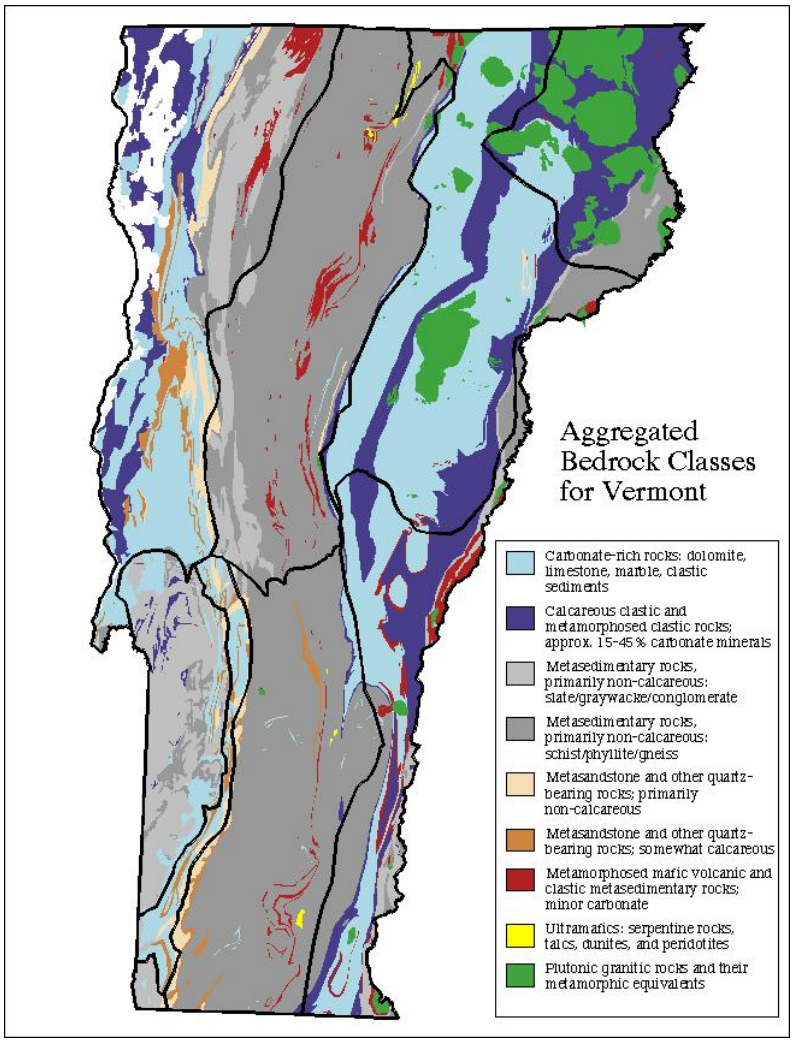
Aggregated
Bedrock Classes
for Vermont
Carbonate-rich rocks: dolomite, limestone, marble, clastic sediments
Calcareous clastic and metamorphosed clastic rocks; approx. 15-45 % carbonate minerals
Metasedimentary rocks, primarily non-calcareous: slate/graywacke/conglomerate
Metasedimentary rocks, primarily non-calcareous: schist/phyllite/gneiss
Metasandstone and other quartz-bearing rocks; primarily non-calcareous
Metasandstone and other quartz-bearing rocks; somewhat calcareous
Metamorphosed mafic volcanic and clastic metasedimentary rocks; minor carbonate
Ultramafics: serpentine rocks, talcs, dunites, and peridotites
Plutonic granitic rocks and their metamorphic equivalents

**Figure 3.4** This map shows the distribution of calcareous and non-calcareous bedrock types in Vermont. Lake water quality studies conducted by the Vermont Department of Environmental Conservation have shown that bedrock type heavily influences lake buffering capacity, with those lakes having the lowest alkalinities (generally < 25 mg/l) occurring in areas dominated by non-calcareous bedrock types (Clarkson 1982). Though data is insufficient to compare stream alkalinity with bedrock type in Vermont, it can be presumed that, in general, stream alkalinity levels follow a similar pattern.